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ERRATA

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Air Force Rocket Propulsion Laboratory

Edwards AFB, California

1. Page 5: Last line - Change "effort" to "effect".

2. Page 7: Table 1, Propellant Type, Stage I, Wing I - Change "PBAA" to "PBAA-AN".

3. Page 5: Delete subtitle, "A.1 General" from first paragraph and renumber all successive subsections in Section IIIA accordingly, i.e.,

   Change "A.2" to "A.1" on Page 5

   Change "A.2.1" to "A.1.1" on Page 5

   Change "A.2.2" to "A.1.2" on Page 6

   Change "A.2.3" to "A.1.3" on Page 8

   Change "A.2.4" to "A.1.4" and "A.2.5" to "A.1.5" on Page 10

   Change "A.3" to "A.2" on Page 13

   Change "A.4" to "A.3" on Page 16

   Change "A.5" to "A.4" on Page 22

4. Page 17: Table III - Third column heading - Change "A6C" to "AGC".

5. Page 18: Table IV - Third column heading - Change "A6C" to "AGC".

6. Page 86: Insert Page 92 between Pages 86 and 87.

7. Page 136: Insert Page 151 between Pages 136 and 137.

8. Page 145: References C.23.3 and C.23.4 - Change "C.60.1" to "C.23.1".

CONFIDENTIAL

(U) SPECIAL REPORT:
BIBLIOGRAPHY OF SOLID ROCKET COMPONENT AGING

John L. Myers
Edwin L. Moon
Lemuel R. Allen

TRW SYSTEMS

GROUP-4
DOWNGRADED AT 3 YEAR INTERVALS;
DECLASSIFIED AFTER 12 YEARS

This document contains information affecting the national defense of the United States within the meaning of the Espionage Laws, Title 18, U.S.C., Section 793 and 794, the transmission of which in any manner to an unauthorized person is prohibited by law.

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FOREWORD

The work reported herein was sponsored by the Air Force Rocket Propulsion Laboratory, Research and Technology Division, Edwards, California, under Contract AF 04(611)-11392, BPSN 623059, Project 3059. The project officer was David L. Pilkington, 1/Lt/USAF/RPMCH.

This report, the first of two technical reports required by the contract, presents the results of the work performed during the period 3 January to 1 April 1966. Some of the references herein were extracted from Confidential documents and are so noted. The work was conducted by personnel of the Chemistry Department, TRW Systems, Redondo Beach, California, and managed by B. Dubrow. The major portion of the technical effort was performed by J.L. Myers, (Principal Investigator), E.I. Moon, and L.R. Allen. Acknowledgments are also made to Miss E. M. Christman, C. J. Coons, and R. C. Nordberg, who provided assistance in searching the literature and organizing the references; also to Miss A. Huntington for editing the report.

UNCLASSIFIED ABSTRACT

This report is intended to provide a single source reference document to literature dealing with aging and surveillance studies of solid rocket motor components and surveillance techniques. The bibliography contains over 1000 references, of which about 400 pertain to the MINUTEMAN Aging Program. Major emphasis has been given to the MINUTEMAN Program because TRW's participation in this program from its onset permitted a detailed review which should be of value to others planning new aging programs. Selected references are provided on 23 categories of solid rocket motors in addition to MINUTEMAN. Many reports are referenced which contain extensive information on the aging of the materials and components that are commonly used in solid rocket motors. The collected references are catalogued in a logical manner, and a narrative section is provided as a guide to the scope and nature of the references. Analysis and assessment of the collected literature on rocket component aging will be presented in a later report, which will include an updated bibliography.

CONTENTS

GLOSSARY

ABL	Allegany Ballistics Laboratory
A/D	Arm/disarm
AFBSD (or BSD)	Air Force Ballistic Systems Division
AFLC	Air Force Logistics Command
AFSC	Air Force Systems Command
AGC	Aerojet-General Corporation
ageout	Decision point for retrofit replacements
ARPA	Advanced Research Projects Agency
ASTM	American Society for Testing Materials
CPIA	Chemical Propulsion Information Agency
component	Functional Unit of Subsystem
DDC	Defense Documentation Center
EPU	Electrical power unit
Failure criteria	Limits assigned to identify service life
FTM	Flight test missile
G and C	Guidance and control
HPC	Hercules Powder Company
ICRPG	Interagency Chemical Rocket Propulsion Group
ITS	Inertial timer switch
JANAF	Joint Army-Navy-Air Force Groups
LGM 30	Air Force designation for MINUTEMAN missile
MAC	Motor Associate Contractors
N/A	Not applicable (or available)
NOL	US Naval Ordnance Laboratory
NOTS	US Naval Ordnance Test Station
NPP	US Naval Propellant Plant
NPF	US Naval Powder Factory
OOAMA	Ogden Air Material Command
Pen Aid	Devices to assist in penetration of defenses
R and D	Research and Development
retrofit	Replacement of Parts
retro tumble	Control Rockets
RIP	Reliability Improvement Program

RV	MINUTEMAN atmosphere reentry vehicle
S and A	Safe and Arm
service life	Useful Operational Life of the Item
SN	Serial Number
SPIA	Solid Propellant Information Agency
STL	Space Technology Laboratories
SWG	Surveillance Working Group
TCC	Thiokol Chemical Corporation
TRW Systems	Thompson, Ramo, Wooldridge
TT	Thrust Termination
TVC	Thrust Vector Control
WH	Warhead
Wings I - VI	Groups of Missiles Manufactured and Deployed Within Sequential Periods of Time
WS/133	Air Force Designation for Complete MINUTEMAN Weapon System, Including Logistic Support Equipment

SECTION I

INTRODUCTION

This report presents the results of the Phase I portion of a program designed to assess the present state-of-the-art of solid rocket motor component aging and to define the effort required to advance this technology. The objective of the Phase I effort, described herein, was to compile and organize a single source reference document on solid rocket motor component aging. The Phase II and III portions of the program will consist, respectively, of an assessment of the data gathered in Phase I and the preparation of recommendations for future effort. The results of the assessment and recommendations will be published in the Final Report along with an updated bibliography.

The present bibliography on solid rocket motor component aging contains all of the documented literature on the MINUTEMAN Aging Program plus selected references pertaining to the aging and surveillance testing on 23 categories of other solid rocket motors. In addition, references are included which describe the available aging information on 12 different categories of components and materials that are commonly used in solid rocket motors.

Over 1000 references are included in this bibliography, of which approximately 400 pertain to the MINUTEMAN Aging Program. Major emphasis has been given to the MINUTEMAN Program because TRW's participation in this program from its inception has permitted a detailed review to be made which may be of value to others planning new aging programs. Moreover, this valuable data has not heretofore been thoroughly compiled or made available for general usage. Accordingly, a fairly comprehensive description of the available documents is included in (A) of Section III, together with information on the history, development, and usefulness of the aging program.

To supplement the MINUTEMAN aging data, a thorough search was made of the SPIA/CPIA abstracts back to 1956. Also STAR, C-STAR and DDC abstracts were reviewed back to 1963. Many valuable references to other rocket motor aging programs and to the aging behavior of materials and components were obtained. The scope and content of these references are discussed in (C) and (D) of Section III, respectively.

It should be noted that references on propellant aging were not required for this bibliography, since this information is available elsewhere. For completeness, however, some of the key references and review papers have been included.

It is believed that more extensive information on the aging and surveillance testing of other solid rocket motors, components, and materials is still available; therefore, further efforts to obtain more data are planned. In addition, personal contact with selected agencies and facilities will be made now that need-to-know authority has been obtained. Further, the recipients of this report are urged to notify the authors of any pertinent references or unpublished information. All such data will be included in the Final Report.

SECTION II

ORGANIZATION OF BIBLIOGRAPHY

The single source bibliography on the aging of solid rocket motors and components has been organized by subject matter into the following major subsections:

A. MINUTEMAN Aging Programs

B. General Surveillance and Aging Information

C. Other Motor Surveillance Programs

D. Component and Material Aging Reports.

In each major subsection, the scope of the information contained in the bibliography is discussed and the respective references are included immediately following the narrative portion. For further convenience in locating the appropriate references in the bibliography, a decimal system has been used. In general, the decimal system consists of two decimal numbers. The first number is used to classify the references by subject subheading while the last number refers to the chronological order of the references. In some instances (Subsection B), the diversity of subject matter did not permit use of the first digit (subject subheading), while in Subsection A, a third decimal number is added because further sub-classification appeared useful. In all instances, the last decimal number refers to the chronological order of the references.

While the system described above is useful for the interim report bibliography, a more detailed decimal system will be utilized in the Final Report. This detailed system will provide rapid and more specific retrieval of information, possibly by punch card methods, and will be "open-ended" so that additions can be made. The system visualized will identify, as a minimum, (1) weapon system, (2) subject matter, (3) type of information, (4) type of document, (5) agency issuing report, (6) report number, and (7) date of publication.

Because of the comprehensive nature of the bibliography and background available on the MINUTEMAN Program, the narrative portion of the report has been organized to provide an insight into the historical and logical developments of the Aging Program, as well as a discussion of the contents of the bibliography.

SECTION III

LITERATURE SURVEY

III-A MINUTEMAN MOTOR AGING PROGRAM

A.1 General

The purpose of this section of the bibliography report is to summarize the scope and content of the MINUTEMAN Motor Aging Program and to provide a complete list of all the reference documents on the program that have been published. Over 400 documents are referenced in this bibliography. For convenience, these references are organized and discussed under the following major headings:

History and Background
Program Planning
Surveillance Techniques
Aging Program Results.

Instead of providing abstracts for each of the MINUTEMAN references, the following discussion reviews in some detail the type of information available on each subject, identifies key references, and at the same time outlines the MINUTEMAN Aging and Surveillance Programs in sufficient detail to inform the reader of the approach and techniques used. To provide further background, the MINUTEMAN propulsion system is described, and a fairly extensive review of the history and need for an aging program is included.

A.2 History and Background

A.2.1 General Description of MINUTEMAN Weapon System

The LGM 30 MINUTEMAN weapon system contains three propulsion stages which must deliver a payload with the required accuracy and range of an ICBM deterrent weapon, meeting narrow performance requirements to insure conformance with a pretargeted ballistic trajectory. Consequently, the reliability of the weapon system is a composite of the reliability of the many individual and interacting components. Changes which may occur as a result of age must be identified, assessed in terms of aging rate, and evaluated in terms of effort on the overall system. It is also necessary

to identify variations in aging which occurred because of using different manufacturers for the various subsystems.

The propulsion subsystems for the LGM 30 MINUTEMAN Weapon System consists of three solid propellant motors that are dissimilar in construction, materials, and fabrication methods. The basic characteristics of the three stages are shown in Table I.

The first stage motor is manufactured by Thiokol Chemical Corporation, Brigham City, Utah; the second stage by Aerojet-General Corporation, Sacramento, California; and the third stage by Hercules Powder Company, Magna, Utah.

The production of the LGM 30A configuration was started in November 1961. One hundred and fifty missiles of this configuration were deployed in the operational force as Wing I. Propulsion subsystem design modifications resulted in a new missile configuration, designated as LGM 30B. Six hundred and fifty missiles of this basic configuration were subsequently emplaced as the Wings II through V operational force. Most recently, the second stage motor was completely redesigned for the LGM 30F missile (Wing VI). Minor design modifications were also made to the first and third stage motors to improve reliability. For surveillance purposes, the changes (Stage I and III) are considered to be minor.

A.2.2 <u>Justification for the Aging Program</u>

The MINUTEMAN Motor Aging Program was initiated early in the development phases of the MINUTEMAN propulsion subsystem. The requirement for long-term operational service life of the MINUTEMAN motors was recognized at the inception of the development programs. It was considered that a 3-year storage capability was a minimum requirement, and a 10-year service life was planned as the design goal. A key element in accomplishing these objectives lies in the knowledge of the aging characteristics of the MINUTEMAN motors and components stored under operational conditions. At some point it must be expected that the reliability of the motors will be degraded due to aging. Planning for replacement or rework of operational motors necessitates continuous monitoring of full-scale motor aging and the relatively early determination of modes of failure which occur during storage. The failure must be

Table I. Characteristics of MINUTEMAN Propulsion Subsystem

ITEM	STAGE I		STAGE II			STAGE III	
	WING I	WING II	WING I	WING II	WING VI	WING I	WING II
Contractor	Thiokol	Thiokol	Aerojet	Aerojet	Aerojet	Hercules	Hercules
Weight (Pounds)	50,000	50,000+	11,000	11,000	15,000	4,000	4,000
Length (Feet)	24	24	13	13	13	7	7
Diameter (Inches)	66	66	44	44	52	38	38
Nozzles	4 movable	4 movable	4 movable	4 movable	1 fixed w/ LITVC	4 movable	4 movable
Case material	Ladish Steel	Ladish Steel	Ladish Steel	Titanium	Titanium	Fiberglass (Spiralloy)	Fiberglass (Spiralloy)
Propellant Config.	6 point star	6 point star	4 point star	4 point star	Finocyl	Slotted Tube Cone	Slotted Tube Cone
Propellant Type	Composite	Composite	Composite	Composite	Composite	Double Base	Double Base
Propellant Composition	Ammonium Perchlorate	Ammonium Perchlorate	Ammonium Perchlorate	Ammonium Perchlorate	Ammonium Perchlorate	Ammonium Perchlorate	Ammonium Perchlorate
	PBAA	PBAA-AN	Poly-urethane	Poly-urethane	CTPB	Nitro-cellulose	Nitro-cellulose
	Epoxy Curing Agent	Epoxy Curing Agent	TDI Curing Agent	TDI Curing Agent	BITA Curing Agent	Nitro-glycerine	Nitro-glycerine
	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
Igniters	1	1	1	1	1	1	1
Thrust Termination Assembly	-	-	-	-	-	1	1
External Insulation	Avcoat	Avcoat	Avcoat	Avcoat	Cork	Avcoat	Avcoat/Cork
Start of Operational Production	Nov 61	Nov 62	Mar 62	Dec 62	Jan 65	Dec 61	Nov 62

analyzed, corrective action determined, and a decision made as to motor disposition in sufficient time to be phased into the recycle and rebuy schedules. Inadequate or misleading aging information may result in an overly conservative decision on motor disposition, which would then tend to increase motor replacement cost. On the other hand, an overly optimistic decision could compromise the deterrent capability of the weapon system. Therefore, a carefully planned technical program providing sufficient lead time for hardware procurement and production forms a basis for management cost planning. For these reasons a comprehensive R and D surveillance program was established at the outset of MINUTEMAN motor development.

A.2.3 Initial Program Planning

Reference A.1.3 provides the guidelines and basic planning on which the MINUTEMAN Aging Program was based. Following is a summary of essential ground rules used in planning this program:

1) The number of variables must be limited by restricting the storage conditions for the full-scale motors to the operational environment.

2) The program must be planned to insure that a maximum amount of pertinent data is obtained from each test.

3) A complete component and material aging program must be planned to support the full-scale aging program.

4) The operational surveillance program should utilize the initial test firing information from the R and D aging program, thereby reducing the need for early motor sampling from the operational force.

5) Maximum use must be made of planned operational tests.

6) Maximum use of existing equipment and facilities must be planned to minimize cost.

The available facilities required to store and test the full-scale motors were reviewed, and in early 1960 BSD decided that the most desirable approach to aid in the transition from the R and D to operational surveillance program would be to modify and construct new facilities for motor storage at OOAMA. Reference A.1.1 defines the motor storage facility requirements and provides the essential design criteria.

As initially conceived, the MINUTEMAN Aging Program consisted of three integrated phases:

1) A full-scale R and D motor program containing approximately 20 motors of each stage for Wing I configuration and 10 of each stage for the Wing II configuration. To provide lead time over the operational force, all motors were early production motors or early development motors having configurations similar to operational. The motors were allocated at random to reduce the bias of time of manufacture, and the test matrix which covered a 10-year period permitted evaluation of horizontal and vertical storage conditions. Because the primary objectives of the R and D aging program were to demonstrate the storage capability and reveal possible failure modes in the basic motor design rather than the as-built motor, it was considered than ten Wing II motors were adequate in view of the fact that the configuration was not significantly different from Wing I.

2) A laboratory and component program to supplement the motor program and provide greater confidence in the adequacy of the motor design without the expense of firing sufficient motors to demonstrate the required long-term reliability. The laboratory program also permitted evaluation of a wide range of environmental conditions at low cost. In addition, aging trends could be measured more readily in the laboratory program and estimates of predicted service life could be obtained knowing the function and failure mode of each component. Unlike other programs, the laboratory phase included a wide range of materials and components besides propellants. All age-sensitive materials whose degradation might affect the performance and reliability of the propulsion system were included, such as insulation materials, bonds, seals, lubricants, adhesives, and plastics. In addition, the aging behavior of assembled components, including igniters, nozzles, safe and arming devices, and other ordnance devices were studied to provide a better assessment of possible interactions. In most cases only the effect of operational or logistic storage conditions were evaluated, but some accelerated aging tests were conducted early in the program to obtain early data on aging characteristics and probable failure modes.

3) An operational motor storage program consisted of ten Wing II motors of each stage, to be drawn at random from the operational force during recycle. Half of these were scheduled to be tested over a 10-year period as flight test missiles in the combat training launch program and half as static motor tests. These tests permitted statistical comparison between the motors stored separately in the R and D silos and those obtained from operational missile sites. In addition, they provided assurance that flight performance would not be affected by long-term storage.

A.2.4 Development of Operational Surveillance Program

The operational surveillance program has undergone considerable change since its conception. The initial plan, as described in Reference A.1.2, was revised to make better use of the extensive information that was available from the R and D aging program and better achieve its objectives of defining the ultimate service life and reliability of the MINUTEMAN propulsion system. The number of test motors to be withdrawn during recycle from the operational force was revised to seven Wing I and 17 Wing II motors from each stage. In addition, plans were made to incorporate 15 of the new Stage II/Wing VI configured motors. Plans were also initiated to remove some aged ordnance components from operational motors during recycle and test in the operational surveillance program. In addition to these ordnance components, the operational surveillance program has always included some propellant testing. This phase differed from the R and D aging program, however, in that it included representative batches from nearly every operational motor. These batches, which were obtained from the Motor Associate Contractors (MAC's) during manufacture, were subjected to initial tests, then retested approximately every 18 months thereafter. Because of the large number of samples involved, only uniaxial tests were performed routinely; all other propellant tests were conducted in accordance with a predetermined matrix.

A.2.5 Development of Overall Aging Program

The evolution and development of both the operational and R and D surveillance programs is described in the next subsection, "Program Planning." A summary of the history of the overall program is also provided in Table II. The review papers in References A.1.6 to A.1.9 should also be consulted for information on the changes that have taken place since the inception of the program. Reference A.1.4 outlines the basic philosophy and technical approach of the original R and D aging program; Reference A.1.6 describes the actual aging program that was conducted up to 1965.

In general, the present program is not very different from the original concept. Some revisions were made to the motor program and

Table II. Surveillance Program History

Establishment of R and D Requirements Minimum - 3 Years Design Goal - 10 Years	July 1958
Definition of Overall Program Full-Scale Motor Component Laboratory	1959
Decision to Store R and D Motors at OOAMA	March 1960
Definitive Full-Scale Motor Plan	July 1960
Facilities Design Criteria	September 1960
First Storage Motor Committed to Surveillance Program Stage I—August 1960 Stage II—August 1960 Stage III—September 1960	
Initial Operational Surveillance Plan	Mid 1961
Establishment of MINUTEMAN Surveillance Working Group	February 1962
Wing VI Surveillance Program	End 1962
Wing I Minimum Estimated Service Life at 4 Years	June 1963
3-Year Surveillance Motor Fired Stage I—January 1964 Stage II—June 1964 Stage III—June 1964	
Wing I and II Minimum Estimated Service Life at 4-1/2 Years	June 1964
Transfer of Wing I Motor Surveillance Program to OOAMA	July 1964
Wing I and II Minimum Estimated Service Life at 5 Years	May 1965

additional laboratory and component specimens were assigned to provide information of new design changes and greater coverage of suspect items.

In 1963 a combined laboratory and motor aging program was started for the Stage II Wing VI motor, and in 1964 the scope of each of the laboratory and component programs was increased to provide test specimens for a 10-year program. This was accomplished partly by rescheduling and partly by use of reserve specimens. Plans were also initiated to determine the feasibility of dissecting full-scale motors so that additional aged samples could be obtained, and also that additional validity on the laboratory program would be obtained by a comparison of laboratory and motor-aged samples.

In July 1964 the engineering and systems management responsible for the LGM 30A full-scale motor surveillance program was transferred from AFSC/BSD to AFLC/OOAMA. The details of this transfer are provided in Reference A.1.5.

Beginning in 1965, the objectives of the program were reassessed and several major revisions made. These changes were based in part on the following factors:

1) The entire Wing I through V Aging Program was scheduled for transfer to OOAMA in July 1966.

2) The present program was not consistent with force modernization plans.

3) Increased confidence in service life estimates was needed as the age of the motors in the field increased.

4) More realistic failure criteria and standardized procedures for estimating service were required.

5) A systematic plan of action was needed to confirm any suspected age-out condition.

6) Better replacement/retrofit plans were necessary to insure the prompt action necessary to protect the force.

7) A data storage and retrieval program was necessary to handle the increasing quantity of aging data.

The corrective measures taken during FY65 and 66 to implement these changes are discussed and referenced in the subsections which follow.

A. 3 Program Planning

As explained in the preceding subsection, basic planning for the MINUTEMAN Aging Program was initiated by Space Technology Laboratories (which became TRW Systems Group in July 1964) in support of the Air Force Ballistic Systems Division (AFBSD). Using the guidelines that evolved from this initial planning, each motor associate contractor (MAC) developed individual surveillance program plans for his respective propulsion subsystems. Because of differences in motor configuration, design criteria, and facilities, the resulting programs differed somewhat in scope and experimental approach. This was especially true in the laboratory and components programs. Nevertheless, this approach had the advantage of utilizing to the fullest extent the experience and knowledge that each contractor had obtained during the development and qualification of the motor. The same technical approach was preserved throughout the overall program, however, insured by periodic review and approval by BSD/TRW.

To provide an insight into the evolution of the MINUTEMAN Aging Program, references are provided to all available program plans, including those that have since been superseded. These references are arranged in the following order:

1) Thiokol Chemical Corporation	Stage I, Wing I through VI, Aging Program
2) Aerojet-General Corporation	Stage II, Wing I through VI, Aging Program
3) Hercules Powder Company	Stage III, Wing I through VI, Aging Program; Retro Tumble Rockets made by Hercules Powder Company, Kenvil, New Jersey
4) OOAMA	Operational Surveillance Program on LGM 30 propulsion and ordnance components
5) TRW Systems	Overall MINUTEMAN Surveillance Program Plan
6) Miscellaneous	Aging programs for the propulsion and ordnance devices in the penetration aid and tumble rockets made by Hercules Powder Company, Kenvil, New Jersey

In general, these program plans are the best source of information on the scope and content of the individual programs. They also describe the objectives, the overall technical approach, program requirements and planning, and schedules for the motor tests and laboratory phases of the program. Details on special tasks such as the development of failure criteria, structural analysis, aging mechanism, and motor dissection studies are also discussed therein. Details on test methods, storage conditions, sample description, and data analysis procedures are generally included in the individual test plans. These are discussed and referenced in Subsection A.4, "Surveillance Techniques."

It will be noted on inspection of the references that the program planning information and test plan detail are often combined. For example, on the Thiokol program, the initial effort on aging is contained in the individual test plans. Aerojet-General, on the other hand, issued a combined program plan, but initially called it a test plan. The reader should therefore consult the references in the test plan section as well as this section to obtain complete information on the overall program.

In all cases the program plans are considered working documents and each motor contractor has been required to update and revise the program to reflect current practice and redirection. An indication of the kinds of revisions that were implemented throughout the program can be obtained by comparison of the old and new program plans. In general, the following philosophy prevailed. Initially, heavy emphasis was placed on the laboratory program, especially the accelerated aging tests. Simultaneously, long-term aging programs were initiated for both motors and components. As the program progressed, laboratory emphasis was shifted slowly from material evaluation to studies designed to provide confidence in the predicted service life. At the same time, the number of motor tests increased as more motors became available from force modernization and as the operational surveillance program increased in size. Additional data also became available for the operational flight training program.

At the present time plans are in progress to increase the motor test program to confirm the present predicted life with high confidence and to use the laboratory program only for failure analysis and the study of new design features. The best reference to these later developments is the

TRW Systems Master Surveillance Program Plan (Reference A.2.30). This report also summarizes the overall effort on each propulsion subsystem and the operational surveillance program up to the present time. The current effort, which is described in detail, includes:

1) Standardized procedure for estimating minimum service life

2) Systematic plan for confirming a suspected age-out condition

3) Criteria for replacement or retrofit of the force

4) Data storage and retrieval program.

Details on program management, program changes, and the plans to transfer the aging program to OOAMA are also provided.

A.4 Surveillance Techniques

The individual test plans prepared by the testing agencies (including OOAMA and the MAC's) are the primary reference documents for information on the test procedures and techniques used in the MINUTEMAN Aging Program to determine the aging characteristics of MINUTEMAN motors and components. These test plans describe in detail the test requirements for each individual aging study, such as:

a) Limits and type of environment
b) Type of equipment used
c) Handling procedures
d) Sampling procedures
e) Types of tests used
f) Detailed test procedures or a suitable reference if a standard tests are used
g) Methods for data analysis
h) Reporting requirements.

Test plans are included in the bibliography as References A. 3.1.1 to A. 3.1.52. These test plans cover the three propulsion subsystems, the retro and tumble rocket motors, and the ordnance devices associated with the initiating, separating, or terminating functions of the missile system. In some cases (for example, Stage III) the individual test plans for the materials, components, and subassemblies are included as part of the general program plan. The latter should always be consulted in any event with regard to Stage III. as it outlines the overall technical approach.

It will be noted from the references that frequent revisions are made to the test plans. Wherever possible, the revisions have been listed to provide evolutionary information on the final test plan, and to indicate the types of improvements that were made during the program. For convenience, the test plans are also listed in matrix form for the three motor stages (Tables III and IV). By referring to these tables, the reference numbers in this bibliography and the contractor test plan number for any component, material, or subassembly tested can readily be found. Only a few of the test plans for individual full-scale motor firings have been referenced, since these test plans are considered sub-tier to the documentation on motor firings which is given in the Motor Firing Final Report.

Table III. MINUTEMAN Propulsion Storage Program, Wings I Through V, Matrix Index to Detailed Storage Test Plans

	Stage I		Stage II		Stage III	
	TCC Doc. No.	TRW Ref. No.	A6C Doc. No.	TRW Ref. No.	HPC Doc. No.	TRW Ref. No.
Full Scale Motors	IT 2200 IT 2576	A.3.1.19 A.3.1.17	0162-01PP-6 0162-AS-2-1 PD A01 TP A01 TP 598 TP 662 TP 620	A.2.10 A.2.7* A.2.7* A.2.7* A.3.1.33 A.3.1.18 A.3.1.20	MTO-258-3A, Revision 2, Chapter II	A.2.11
Propellant	TWR 596	A.3.1.14	TP 720 PD A06 TP A06	A.2.9* A.2.7* A.2.7*	Chapter 3 Section VII	A.2.11
Insulation	TWR 600 TWR 1614	A.3.1.8 A.3.1.2	TP 720 PD A05 TP A05	A.2.9* A.2.7* A.2.7*	Chapter 3 Section IX, X, XI	A.2.11
Nozzles and Pressure Seals	TWR 720 IT 2576 IT 3848	A.3.1.11 A.3.1.17 A.3.1.16	TP 720 PD A04 TP A04	A.2.9* A.2.7* A.2.7	Chapter 3, Section V, XII	A.2.11
Igniters	TWR 399 TWR 467 TWR 469 TWR 691 IT 2461 IT 2484 IT 3205 IT 3322	A.2.5 A.3.1.5* A.2.1* A.3.1.13 A.3.1.5* A.3.1.15 A.3.1.5* A.3.1.5*	TP 720 PD A03 TP A03	A.2.9* A.2.7* A.2.7*	Chapter 3, Section I, II	A.2.11
Liners and Sealants	TWR 597 TWR 721	A.3.1.7 A.3.1.9	(See Propellant and Insulation)		Chapter 3, Section VIII, XIII	A.2.11
Safe and Arm	TWR 648 TWR 664 TWR 270 IT 2485	A.3.1.12 A.3.1.10 A.3.1.5* A.3.1.5*	See Stage I		See Stage I	
Miscellaneous Ordnance Devices	TRW 1368	A.3.1.5	See Stage I		MTO-752-35 MTO-258-3A Revision 2, Chapter 3, Section III, IV	A.2.14 A.2.11
Failure Criteria	TWR 705 TWR 712 TWR 1644 TWR 1643 TWR 1688	A.3.3.2 A.3.3.1 A.3.2.1 A.3.2.2 A.3.4.1	-	A.2.7	MTO-752-35 MTO-258-3A Revision 2, Chapter 4 Section I-IV	A.2.14 A.2.11
Motor Case	N/A	N/A	N/A		MTO-752-35 MTO-258-3A Revision 2, Chapter 3 Section VI	A.2.14 A.2.11

*Indicates a subtier document in the given reference.

Table IV. MINUTEMAN Propulsion Storage Program, Wing VI, Matrix Index to Detailed Storage Test Plans

	Stage I		Stage II		Stage III	
	TCC Doc. No.	TRW Ref. No.	A6C Doc. No.	TRW Ref. No.	HPC Doc. No.	TRW Ref. No.
Motor (Program)	TWR 1635	A. 2. 4	IM 034	A. 3. 1. 24	MTO-258-3A Revision 2 Chapter II	A. 2. 11
Motor (Test Plan)	TWR 1272	A. 3. 1. 18	A52A	A. 2. 6*		
Propellant	TWR 596	A. 3. 1. 14	IM 032 IM 105 A56A A57A	A. 3. 1. 32 A. 3. 1. 23 A. 2. 6* A. 2. 6*	Chapter 3 Section VIII	A. 2. 11
Insulation	TWR 1614	A. 3. 1. 2	IM 040 A55A	A. 3. 1. 29 A. 2. 6*	Chapter 3, Sections IX, X, XI	A. 2. 11
Nozzles and Pressure Seals	TWR 1716	**	A54A	A. 2. 6*	Chapter 3, Sections V, XII	A. 2. 11
Igniters	TWR 1368	A. 3. 1. 5	IM 042 A53A	A. 3. 1. 21 A. 2. 6*		
Liner and Sealant	TWR 597 TWR 721	A. 3. 1. 7 A. 3. 1. 9	(see Propellant)		Chapter 3, Sections I, II	A. 2. 11
LITVC	N/A		A58 A59 A60 A61 A62 IM 041 IM 108 IM 109 IM 112	A. 2. 6* A. 2. 6* A. 2. 6* A. 2. 6* A. 2. 6* A. 3. 1. 39 A. 3. 1. 26 A. 3. 1. 25 A. 3. 1. 22	N/A	
Safe and Arm	TWR 1368	A. 3. 1. 5	Same as Stage I		See Stage I	
Aft Closure	TWR 1678	A. 3. 1. 3	N/A	N/A	MTO-258-3A, Revision 2 Chapter 3, Sections I, II	
Miscellaneous Ordnance Devices	TWR 1368	A. 3. 1. 5	See Stage I		MTO-752-35 MTO-258-3A Revision 2, Chapter 3, Section III, IV	A. 2. 14 A. 2. 11
Failure Criteria	TWR 705 TWR 712 TWR 1644 TWR 1643 TWR 1688	A. 3. 3. 2 A. 3. 3. 1 A. 3. 2. 1 A. 3. 2. 2 A. 3. 4. 1	--	A. 2. 7	MTO-752-35 MTO-258-3A Revision 2, Chapter 4 Section I-IV	A. 2. 14 A. 2. 11
Motor Case	N/A	N/A	N/A		MTO-752-35 MTO-258-3A Revision 2, Chapter 73 Section VI	A. 2. 14 A. 2. 11

*Indicates a subtier document in the given reference.

**This test plan was not published in time for inclusion in this report; however, it will be included in the Final Report

In most cases, the test methods used by the motor contractors differ in detail because of differences in motor configuration or test equipment. Wherever possible, however, similar test methods are employed so that the results may be correlated and the testing program on similar materials reduced. Table V provides a partial listing of tests which are common to the three motor contractors. References A.3.2.3 to A.3.2.15 document efforts which have been made to correlate results of test methods between facilities, particularily between OOAMA and the motor contractors. With this information the same failure criteria can be used by OOAMA, and the extensive aging data obtained by the motor contractors can be used to assess the operational program results. References are also given to certain documents which describe studies made in the MINUTEMAN Program to develop improved test methods for some materials and components. Standard test methods are not referenced, since these are adequately documented in the respective test plans.

One of the major requirements in estimating minimum service life is the need for failure criteria to assess the trend data and determine when the level of degradation would probably cause a critical motor failure.

Early in the program it was recognized that manufacturing or acceptance specifications were not entirely adequate, since they defined the present level of experience rather than the limit beyond which failures could be expected. As more aging data became available, it was realized that the development of realistic failure criteria was essential for the accurate estimation of service life. Consequently, in 1965 extensive effort was initiated in the MINUTEMAN Aging Program to establish failure theories and failure limits for age-sensitive materials and components that were consistent with the overall system requirements. References A.3.3.1 to A.3.3.15 describe the technical approach being used and the types of failure criteria being developed.

A number of references are also provided to document the statistical procedures used in the MINUTEMAN Aging Program to determine the best estimate of demonstrated reliability and confidence level on the basis of continued successful firings of aged motors.

Table V. Summary of Solid Rocket Motor Component and Material Test Methods

Igniter and Igniter S and A

- Transportation Vibration
- Operational Vibration and Acceleration
- Radiographic NDT
- Static Test Igniter
- Dissection
- Chemical Analysis
- Temperature and Humidity

Igniter Pellets

- Heat of Reaction
- Impact Sensitivity
- Moisture Content
- Vibration Resistance
- Microscopic Examination
- Ignition Study Arc Image
- Closed Bomb

TT A/D Switches

- Transportation Vibration
- Visual Inspection
- Electrical Check
- Operational Vibration and Acceleration
- Rotor Bounce Test
- Hermetic Seal Test
- Insulation Resistance
- Electrical Cycle
- Visual and Microscopic Examination

Frangible Sectors

- Transportation Vibration
- Operational Vibration and Acceleration
- Temperature Conditioning
- Functional Test
- Metallurgical Analysis
- Electrical Check

Nozzles

- Pressure Leak Test
- Cold Torque
- Radiographic NDT
- Visual Inspections
- Cycling Sequence
- Hand Actuation
- Disassembly and Visual Inspection

Metallic Chambers

- Proof Pressure
- Burst Pressure
- Tensile Strength
- Elongation
- Area Reduction
- Corrosion Resistance
- Metallographic Examination

Reinforced Plastic Chambers

- Proof Pressure
- Burst Pressure
- NOL Ring Tensile Test
- Shear Tests
- Corrosion Resistance

Propellant

- Chemical Analysis
- Stress Relaxation
- Vibrating Disc
- Tensile Strength
- Shear Strength
- Moisture Content
- Density
- Analysis of Gaseous Decomposition Products
- Surface Migration
- X-Rays

Case Bond

- Tensile Test
- 90° Peel Test
- 180° Peel Test
- Chemical Profile

Table V. Summary of Solid Rocket Motor Component and Material Test Methods (Continued)

Internal Insulation

Erosion From Motor Firings
Tensile Tests
Hardness Tests
Chemical Analysis

External Insulation

Shear Tests
Tensile Tests
Hardness Tests
Fungus Resistance Test

Pressure Seals O-Rings

Simulated Ball Joint Cycling
Pressure Leak Test
Break-away Torque
Elongation and Modulus
Compression Set
Tensile Tests
Hardness Test

Adhesives and Potting Compounds

Lap Shear Test
Tensile Test
90° Peel Test
180° Peel Test
Chemical Analysis
Compatibility Tests
Transportation Vibration
Visual Inspections
Photograph Specimens
Shrinkage

References A.3.4.1 to A.3.4.5 describe the procedures that are used in estimating the minimum service life of the MINUTEMAN motor and in identifying the materials and components which appear to be life-limiting. These references outline the basic ground rules, the techniques for data assessment, statistical methods for data trend analysis, extrapolation procedures, and the assumptions made in estimating minimum service life. The references also provide details on the weak link items that have been identified to date and the action that has been taken to resolve problem areas and provide corrective measures.

The early prediction of minimum service life is considered an essential requirement of the MINUTEMAN Aging Program. An estimate based on motor firings alone is of little value unless a sufficient number of aged motors have been fired to provide statistical confidence and the test motors have adequate lead time over the oldest motors in the operational force. In the MINUTEMAN Aging Program, the motor data is integrated with flight test data and combined with the results of a component and subassembly test program to provide a life extension that has a high degree of engineering confidence.

A. 5 Aging Program Results

The progress reports provided by each motor contractor (usually on a quarterly basis) are the primary source of MINUTEMAN aging data. These documents are listed in the bibliography under A. 4. 5, "Progress Reports in the MINUTEMAN Aging Program." The progress report provides an up-to-date summary of all studies underway in both the full-scale motor and laboratory component aging studies. Data trends are discussed and usually plotted on graphs, along with variability limits. Estimates are provided on the service life of each component, weak link items are identified, and special studies to validate service life estimates are presented in detail. These studies include development of meaningful failure criteria to detect the onset of ageout. Progress reports also discuss significant changes in test procedures or program size, and identify problem areas.

The TRW progress reports, included in the bibliography as References A. 4. 5. 61 through -68 provide assessment of the overall aging program data and describe the accomplishments in developing an overall systems approach to reliability degradation. This effort includes:

1) Coordination of the motor contractor's effort and development of uniform procedures for estimating service life and failure criteria

2) Development of a computerized data storage and retrieval program for all data obtained in the aging program

3) Development of replacement/retrofit criteria, including decision-making logic and a program for confirming if an ageout condition exists

4) Establishment of a cost-effective replacement retrofit plan that is consistent with ageout data and Force modernization plans.

The TRW progress reports also describe current program activities, recommendations for program redirection, and the general support provided to BSD/OOAMA.

The final reports for all storage motor firings are also included in this section of the bibliography, since they are the main source of information on the effect of age on motor performance. These reports provide detailed information on each full-scale motor fired in the MINUTEMAN

Aging Program. For example, information is given on

1) Storage history and environment
2) Firing results and interpretation of the data
3) Reference to subtier plans, such as aging test plans, firing test plans, instrumentation
4) Test schedules
5) Motor configuration
6) Discussion of any anomalies.

For convenience, a summary of all the static motor tests in the MINUTEMAN aging program is provided in Table VI. This table permits ready retrieval of any Final Report reference by the propulsion unit stage, by the age of the motor, or by the actual motor number.

It was recognized during the early stages of the MINUTEMAN program that close coordination between Ballistic Systems Division (BSD) OOAMA, TRW, and the MAC's was an essential requirement of the program. Consequently, a Surveillance Working Group (SWG) was formed consisting of both management and technical representatives from each facility. Regular meetings were held in order that the members could be kept informed on the significant features of the MINUTEMAN Aging Program and to insure rapid and appropriate action on current problems. Minutes of meetings of this group are a valuable source of aging information. For example, the SWG meeting minutes provide a summary of the weak link items in each propulsion subsystem, a summary of comments generated by the group, and the action items resulting from these discussions. The minutes of the SWG meeting also provide information on systems interface problems and the program planning which is necessary for an aging program of this scope. The minutes to these meetings are given in the bibliography under References A. 4. 4. 1 through A. 4. 4. 14.

The early returns for the operational aging program being conducted OOAMA are provided in References A. 3. 7. 1 through A.4.7.24. This program was designed to verify the results obtained in the motor contractor's R and D aging program, to provide a larger sample size for estimating reliability degradation, and to insure that undetected deficiencies

Table VI. MINUTEMAN Propulsion Storage Program
Full-Scale Motor Firing Status

Motor Number	Wing	Age (months)	Contractor Report No.	TRW Reference No.
STAGE I				
STM 020	I	15	IT 2608	A. 4. 6. 18
STM 001	I	20	IT 3318 IT 3341	A. 4. 6. 17 A. 4. 6. 16
STM 011	I	20	IT 3705	A. 4. 6. 14
STM 003	I	26	TWR 258 TWR 277	A. 4. 6. 10 A. 4. 6. 11
STM 016	I	27	TW-624-8-63 TW-679-8-63	A. 4. 6. 9 A. 4. 6. 8
STM 019	I	32. 5	TW-532-9-63 TW-677-9-63	A. 4. 6. 6 A. 4. 6. 7
STM 004	I	37. 5	TWR-550	A. 4. 6. 5
STM 010	I	47	TWR-904	A. 4. 6. 3
STM 006	I	55	TWR-1685	A. 4. 6. 2
STM 023	II	24	TWR-770	A. 4. 6. 4
STM 028	II	~36	TWR-1539	A. 4. 6. 1
STAGE II				
A-3	I	14	0162-01TR-A3	A. 4. 6. 29
A-6	I	19	0162-01TR-A6	A. 4. 6. 28
ES-6	I	25	0162-01TR-ES-6	A. 4. 6. 24
SX-9	I	27	0162-01TR-SX-9	A. 4. 6. 27
SX-7	I	30	0162-01TR-SX-7	A. 4. 6. 25
A-1	I	33	0162-01TR-A-1	A. 4. 6. 23
ES-1	I	36	0162-01TR-ES-1	A. 4. 6. 22
ES-7	I	43	0162-01TR-ES-7	A. 4. 6. 20
ES-21	II	24. 8	0162-01TR-ES-21	A. 4. 6. 21
MS-EX-3	VI	22	0. 62-02TR-52MS-EX-3	A. 4. 6. 19
STAGE III				
243B-1-5-20	I	11	MTO-164-45	A. 4. 6. 40
243B-1-5-1	I	16	MTO-164-50	A. 4. 6. 39
243B-1-5-4	I	18	MTO-164-66	A. 4. 6. 38
243B-1-5-5	I	19	MTO-164-98	A. 4. 6. 35
243B-1-5-3	I	25	MTO-164-114	A. 4. 6. 37
243B-1-5-6	I	28	MTO-164-161	A. 4. 6. 34
243B-1-5-10	I	30	MTO-164-126	A. 4. 6. 36
243B-1-5-2	I	49	MTO-164-230	A. 4. 6. 32
243B-1-5-8	I	36	MTO-164-210	A. 4. 6. 33
127A-2-6-1	II	26	MTO-164-241	A. 4. 6. 31

in material or processing has not limited the life of certain groups of motors in the operational Force. At the present time, only limited data are available except for the physical property test data that is obtained on representative propellant batches from each operational motor. It is anticipated, however, that data from the operational aging program will increase significantly now that the testing of motors and ordnance components obtained during recycle has been initiated.

To identify aging trends and anomalies and to assess properly the results obtained in the MINUTEMAN Aging Program, reference must be made to the initial data obtained during the motor development and qualification program. The following references are considered the best sources of information of this type:

a) The Motor Data Books (References A.4.1.1 through A.4.1.11 contain the essential background information on motor design, performance characteristics and materials and components used by each contractor. Referral to these Motor Data Books will provide the configuration detail and associated nomenclature required to interpret aging program results.

b) The Final Reports on the motor development phase summarize the development programs for each propulsion subsystem, the retro/tumble rockets, and the ordnance subsystems. These reports also describe new developments and motor design changes. Both configuration control and knowledge of the design changes are essential for proper interpretation of aging data. The best source of base line data is the final report on the motor qualification program provided by each contractor. These are listed in Subsection A.4.2. The motor contractor development and manufacturing progress reports provide another source of background data. Some of these reports are referenced, but in general only those known to contain information on accelerated aging or environmental testing are included.

c) Special investigations which were conducted during the MINUTEMAN motor development or aging programs are included in References A.4.3.1 through A.4.3.47 and provide information on the planning, data, and conclusions in these programs. These reports provide an insight into the types of failures experienced during the MINUTEMAN Program, the corrective actions that were implemented, and the types of programs that were initiated to evaluate the significance of observed anomalies. The documentation for these special investigations include program plans, test plans, motor firing reports, and final test reports. Selected reports of this type have been referenced to show the scope of effort and illustrate the method of conducting a failure analysis.

A number of special reports containing general information related to the aging program have also been referenced in this section of the bibliography.

In References A.5.1 to A.5.3, detailed information is provided on the procedures used by OOAMA to replace or repair items on the MINUTEMAN missile during retrofit operations. This information is useful in planning corrective actions, since it provides an insight into the difficulties of the various retrofit operations. Also provided is a Reference (A.5.4) which describes the logistic environment of the MINUTEMAN missile system as determined by actual recordings at missile sites.

A. 1 HISTORICAL

A. 1. 1 "Facility Design Criteria for Weapon System 133A Aging Program," Report No. 7750.4-202, Space Technology Laboratory, 28 November 1960.

A. 1. 2 "SM-80 Weapon System Propulsion and Explosive Component Surveillance Program," 2705th Air Munitions Wing, OOAMA, Hill AFB, Utah, July 1961.

A. 1. 3 "MINUTEMAN Surveillance Program, Guide for Aging Program," Report No. 61-9734. 2-1045, Revision 1, Space Technology Laboratory, 2 October 1961.

A. 1. 4 B. Dubrow, "MINUTEMAN Surveillance," Bulletin of the Sixth Meeting of the JANAF-ARPA-NASA Solid Propellant Surveillance Panel, published by SPIA, Silver Springs, Maryland, 5, 6, 7 December 1961.

A. 1. 5 Annex "B" to Tab C of Engineering Transfer Package for MINUTEMAN LGM-30A, Series A, Wing I, TRW Systems, 19 May 1964.

Concerns LGM-30A motor surveillance program transfer to Hill AFB.

A. 1. 6 E. L. Larson, "A Review of the MINUTEMAN Propulsion Surveillance Program for Assessing Rocket Motor Service Life," Report No. AD-467048, CPA/65-1343, (BSD) USAF, Ballistic Systems Division, San Bernardino, California, June 1965.

A. 1. 7 "Final Report, Consolidated Aging Study Program for the LGM 30 Weapon System, vol. I, Summary," Report No. 5295-0501-RU-000, TRW Systems, 30 June 1965.

A. 1. 8 "Final Report, Consolidated Aging Study Program for the LGM 30 Weapon System, col. IV, Propulsion," Report No. 5295-0504-RC-000, TRW Systems, 30 June 1965.

A. 1. 9 "Final Report, Consolidated Aging Study Program for the LGM 30 Weapon System, vol. VI, Airframe and Ordnance," Report No. 5295-0606-RU-001, TRW Systems, 30 June 1965.

A.2 PROGRAM PLANNING

<u>Stage I</u>

A. 2. 1 "Program Plan, MINUTEMAN Motor Surveillance, Stage I MINUTEMAN Motor," Volume I (Preliminary), Report No. WDR0717-62-0967, Thiokol Chemical Corp., Brigham City, Utah, 18 February 1966.

A. 2. 2* "Program Plan, MINUTEMAN Motor Surveillance, Stage I, MINUTEMAN Motors," Volume I, Report No. WDR0717-62-0967, Thiokol Chemical Corp., Brigham City, Utah, 18 February 1966.

A. 2. 3 "Motor Surveillance Reliability Improvement Program Plan" (Preliminary), Report No. TWR 1635, Rev. 2, Thiokol Chemical Corp., Brigham City, Utah, 16 February 1966.

A. 2. 4 "Preliminary Motor Surveillance Reliability Improvement Program Plan," Report No. TWR-1635, Thiokol Chemical Corp., Brigham City, Utah, 4 January 1966.

A. 2. 5 "Program Plan, Stage I, MINUTEMAN, Motor System Storage," Rev. A, Report No. TWR 399 ODR 64-18, Thiokol Chemical Corp., Brigham City, Utah, 11 May 1964.

<u>Stage II</u>

A. 2. 6 "Ten-Year Aging Program for Wing VI MINUTEMAN Second Stage Motors and Components, Program Plan," Report No. 0162-AS-6-1A, Aerojet-General Corp., Sacramento, California, 1 November 1965.

A. 2. 7 "Program Plan, Ten Year Aging Program for Wings I-V, MINUTEMAN Second Stage Motors and Components," Report No. 0162-AS-2-1, Aerojet-General Corp., Sacramento, California, 28 July 1965.

A. 2. 8 "Ten-Year Aging Program for Wing VI MINUTEMAN Second Stage Motors and Components," Report No. 0162-AS-6-1, Aerojet-General Corp., Sacramento, California, 30 April 1965.

A. 2. 9 "Detailed Component and Laboratory Aging Test Plan," Report No. TP720, Aerojet-General Corp., Sacramento, California, 17 October 1961.

A. 2. 10 "MINUTEMAN Stage II, Detailed Program Plan," Report No. 0162-01PP-6, vol III, Aerojet-General Corp., Sacramento, California, 1 June 1961.

* This reference inadvertantly duplicated; see A. 2. 1.

A. 2 PROGRAM PLANNING (Continued)

Stage III

A. 2. 11 "Motor Storage Studies Program Plan," Report No. MTO-258-3A, Rev. 2, vol. I and vol. II, Hercules Powder Co., Magna, Utah, 15 January 1966.

A. 2. 12 "Motor Storage Studies Program Plan," Report No. MTO-258-3A, Rev. 1, Change 1, Hercules Powder Co., Magna, Urah, 1 September 1965.

A. 2. 13 "Motor Storage Studies Program Plan, Weapon System 133A," Report No. MTO-258-3A, Revision 1, Hercules Powder Co., Magna, Utah, 1 September 1965.

A. 2. 14 "Program Plan for Arm-Disarm Switch Diodes Aging Studies," Report No. MTO-752-35, Hercules Powder Co., Magna, Utah, 19 February 1965.

A. 2. 15 "Motor Storage Studies Program Plan," Report No. MTO-258-3A, Revision I, Hercules Powder Co., Magna, Utah, 1 December 1964.

A. 2. 16 "Motor Storage Studies Program Plan," Report No. MTO-258-3A, Hercules Powder Co., Magna, Utah, 31 January 1964.

A. 2. 17 "Phase II Motor Storage Studies Program," Report No. MTO-258-3A, Hercules Powder Co., Magna, Utah, November 1963.

A. 2. 18 "Phase I Motor Storage Studies Program," Report No. MTO-258-3, Hercules Powder Co., Magna, Utah, 17 June 1963.

A. 2. 19 "Storage Program, Operational Transportation Conditioning Plan," Report No. MTO-269-24, Hercules Powder Co., Magna, Utah, 20 January 1963.

A. 2. 20 "Phase II Motor Storage Studies Program," Report No. MTO-258-1, Hercules Powder Co., Magna, Utah, 15 January 1963.

A. 2. 21 "Motor Storage Studies Program," Report No. MTO-258-1, Hercules Porder Co., Magna, Utah, 15 October 1962.

A. 2. 22 "Surveillance Program," Report No. MTO-4-3, Hercules Powder Co., Magna, Utah, 10 September 1960.

A. 2. 23 "Surveillance Program," Report No. MTO-4-2, Hercules Powder Co., Magna, Utah, June 1960.

A. 2. 24 "Surveillance Program (Revision I)," Report No. MTO-4-1, Hercules Powder Co., Magna, Utah, 1 September 1959.

A. 2 PROGRAM PLANNING (Continued)

Stage III (Continued)

A. 2. 25 "Surveillance Program," Report No. MTO-04-6, Hercules Powder Co., Magna, Utah, November 1958.

Retro and Tumble Motors

A. 2. 26 "Aging Program, Retro and Tumble Motors (Rev. No. 5), Wing II MINUTEMAN Reverse Thrust System," Report No. K-35/MR-704-10, Hercules Powder Co., Kenvil, New Jersey, 24 December 1964.

Presents storage test matrix giving firing of retro and tumble rockets as well as overall program plans.

A. 2. 27 "Detailed Program Plan, Retro and Tumble Motor, Design Modification and Service Life Definition," Report No. K-SO-51/RTC-628, Hercules Powder Co., Kenvil, New Jersey, 26 October 1964.

A. 2. 28 "Components Surveillance Program, Section C, Addendum to Reliability Program (Aging)," Report No. K-35/MC-708, Revision 1, Hercules Powder Co., Kenvil, New Jersey, 21 February 1963.

A. 2. 29 "Reliability Program (Aging), Retro and Tumble Rocket Motors," Report No. K-35/MR-704-6, Revision 1, Hercules Powder Co., Kenvil, New Jersey, 30 November 1962.

Propulsion Subsystems, General

A. 2. 30 "MINUTEMAN Weapon System 133A and Weapon System 133B, Propulsion Master Surveillance Plan," Report No. 4459-0106-T7-0001, TRW Systems, 31 March 1966. (C)

Describes total current surveillance effort and associated efforts such as service life estimating procedures for MINUTEMAN Wing I - V and Wing VI.

A. 2. 31 "Explosive Components Surveillance Program for LGM 30 A and B (Wing I thru V) Weapon System," Ogden Air Material Area, Hill Air Force Base, Ogden, Utah, 30 September 1965.

A. 2. 32 "Propulsion Surveillance Program for the M55, M55A1, M56, M56A1, M57, M57A1 Rocket Motors of the MINUTEMAN I (LGM30A and LGM30B) Weapon System," Ogden Air Material Area, Hill Air Force Base, Ogden, Utah, 20 August 1965.

A. 2 PROGRAM PLANNING (Continued)

Propulsion System, General

A. 2. 33 "LGM 30 Testing, Physical and Combustion Test Unit," OOAMA, Hill Air Force Base, Ogden, Utah, September 1964.

Describes technical approach and trend-oriented method of presenting test results in MUNITEMAN operational surveillance program.

A. 2. 34 "Surveillance Program for the M55, M56, and M57 Rocket Motors of the LGM-30A (Wing I) Weapon System," Ogden Air Material Area, Hill Air Force Base, Ogden, Utah, April 1964.

Describes test programs and methods for assessing and reporting on each rocket motor in MINUTEMAN. Includes number of test samples, chemical and physical properties, ballistic tests and data to be obtained.

A. 2. 35 "MINUTEMAN Motor Storage Surveillance Program Plan," Report No. 6650.04-64-630, Space Technology Laboratories, 19 March 1964.

A. 2. 36 "Surveillance Program Plan for the M55, M56, and M57 Rocket Motors of the SM-80A (Wing I) Weapon System," Ogden Air Material Area, Hill Air Force Base, Ogden, Utah, July 1963.

A. 2. 37 "Current and Planned Testing Capabilities for Airmunitions," Ogden Air Material Area, Hill Air Force Base, Ogden, Utah, December 1962.

A. 2. 38 "MINUTEMAN Surveillance Program," Report No. 62-9731.5-806, Space Technology Laboratories (interoffice), 17 August 1962.

Miscellaneous

A. 2. 39 "MINUTEMAN Mk 11A Reentry System Surveillance Program Plan," Report No. RAD-PEF 65-15, Rev. 1, AVCO Corp., Wilmington, Massachusetts, 7 March 1966.

A. 2. 40 "Surveillance Program Plan for Post-Boost Propulsion Subsystem for MINUTEMAN," Report No. 8447-927004, Bell Aerosystems Co., Buffalo, New York, 21 February 1966.

A. 2. 41 "MINUTEMAN Mk 11/11A Penetration Aid Spacer, Surveillance Program Plan," Revision 1, Report No. RAD-U-CC-64-1, AVCO Corp., Wilmington, Massachusetts, 24 August 1964.

A. 2. 42 "AMR MINUTEMAN Safety Standards," Report No. D2-3892, Revision B, Boeing Co., Seattle, Washington, October 1962.

A.3 SURVEILLANCE TECHNIQUES

A.3.1 TEST PLANS

Stage I

A.3.1.1 "Surveillance Test Plan, Reliability Improvement Program, Insulation and Miscellaneous Materials," Report No. TWR-1614, Thiokol Chemical Corp.,

A.3.1.2* "Surveillance Test Plan, Reliability Improvement Program, Insulation and Miscellaneous Material," Report No. TWR-1614, Thiokol Chemical Corp., Brigham City, Utah, 23 February 1966.

A.3.1.3 "Surveillance Test Plan, MINUTEMAN Stage I Closure RIP Configuration," Report No. TWR-1678, Thiokol Chemical Corp., Brigham City, Utah, 21 February 1966.

A.3.1.4 "General Test Plan, MINUTEMAN Stage I Surveillance Motors Reliability Improvement Program Configuration," (Preliminary), Report No. TWR-1272, Thiokol Chemical Corp., Brigham City, Utah, 16 November 1965.

A.3.1.5 "Test Plan, Stage I, MINUTEMAN Motor Ordnance Storage Program," Report No. TWR 1368, Thiokol Chemical Corp., Brigham City, Utah, October 1965.

A.3.1.6** "Test Plan, Stage I, MINUTEMAN Motor Ordnance Storage Program," Report No. TWR-1368, (Preliminary), Thiokol Chemical Corp., Brigham City, Utah, 25 October 1965.

A.3.1.7 "Storage and Accelerated Aging Test Plan, Stage I MINUTEMAN Motor, Wings I and II, Main Case and Aft Closure Liner and Sealant," Revision A, Report No. TWR-597A, Thiokol Chemical Corp., Brigham City, Utah, 10 March 1965.

A.3.1.8 "Storage and Accelerated Aging Test Plan, Stage I MINUTEMAN Motor, Wings I, II and VI, Insulation and Miscellaneous Materials," Revision A, Report No. TWR-600A, Thiokol Chemical Corp., Brigham City, Utah, 26 February 1965.

A.3.1.9 "Storage and Accelerated Aging Test Plan, Stage I, MINUTEMAN Motor, Wings I and II, Bonding System," Revision A, Report No. TWR-721A, Thiokol Chemical Corp., Brigham City, Utah, 26 February 1965.

A.3.1.10 "Compatibility Test Plan, MINUTEMAN Missile, 7U32251 Standardized Igniter Safety and Arming Device," Report No. TWR 664, ODR 64-23, Thiokol Chemical Corp., 23 November 1964.

*This reference inadvertantly duplicated, see A.3.1.1.

**Duplicate, see A.3.1.5.

A.3.1 TEST PLANS (Continued)

Stage I (Continued)

A.3.1.11 "Storage Test Plan, Full-Scale, Stage I MINUTEMAN Motor, Wings I and II, TVC Nozzles," (Revision A), Report No. TWR-720A, Thiokol Chemical Corp., Brigham City, Utah, 15 October 1964.

A.3.1.12 "Test Plan MINUTEMAN Missile, KR 80000-08 Standardized Igniter Safety and Arming Device Long Term Storage," Report No. TWR-648, Thiokol Chemical Corp., Brigham City, Utah, 10 September 1964.

A.3.1.13 "Test Plan Stage I MINUTEMAN Motor, Igniter Loaded Case Assemblies, Storage and Physical Tests after Dissection," (Preliminary), Report No. TWR-691 ODR 64-25, Thiokol Chemical Corp., Brigham City, Utah, 18 August 1964.

A.3.1.14 "Storage and Accelerated Aging Test Plan, Stage I MINUTEMAN Motor, Wing I and II, Main Case and Aft Closure Propellants," Report No. TWR-596, Thiokol Chemical Corp., Brigham City, Utah, April 1964.

A.3.1.15 "Test Plan, Stage I MINUTEMAN Motor Ignitor Case and Propellant Accelerated Aging," Revision A, Report No. IT 2484, Thiokol Chemical Corp., Brigham City, Utah, 15 August 1963.

A.3.1.16 "Storage Test Plan for Full Scale Stage I MINUTEMAN Motor, Wing II, Thrust Vector Control Nozzles," Report No. IT 3848, Thiokol Chemical Corp., Brigham City, Utah, 24 January 1963.

A.3.1.17 "Storage Test Plan for Full Scale Stage MINUTEMAN Motor, Wing I, Thrust Vector Control Nozzles, Part No. U31509," Report No. IT 2576, Thiokol Chemical Corp., Brigham City, Utah, 8 January 1962.

A.3.1.18 "Preliminary General Test Plan, MINUTEMAN Stage I Surveillance Motors, Reliability Improvement Program Configuration," Report No. TWR-1272, Thiokol Chemical Corp., Brigham City, Utah.

A.3.1.19 "General Test Plan for Full-Scale Flight-Weight, Stage I, MINUTEMAN Storage Motors," Report No. IT 2200, Revision 4, Thiokol Chemical Corp., Brigham City, Utah.

A. 3. 1 TEST PLANS (Continued)

Stage II*

A. 3. 1. 20 "Transportation and Handling Test of MINUTEMAN Second-Stage Wing VI, Motor 52TH-4," Report No. 0162-02DR-11, Aerojet-General Corp., Sacramento, California, 18 June 1965.

A. 3. 1. 21 "Igniter System Aging Program," Report No. TP IM-042, Aerojet-General Corp., Sacramento, California, 22 March 1965.

Wing VI Plan.

A. 3. 1. 22 "Transportation Stand Qualification," Report No. TP IM-112, Aerojet-General Corp., Sacramento, California, 10 December 1964.

Wing VI Plan.

A. 3. 1. 23 "Aft End Grain Measurement of Storage Motors," Report No. TP IM-105C, Aerojet-General Corp., Sacramento, California, 30 November 1964.

Wing IV Plan.

A. 3. 1. 24 "Full Scale Motors, Storage and Aging Program," Report No. TP IM-034 C, Aerojet-General Corp., Sacramento, California, 10 November 1964.

Wing VI Plan.

A. 3. 1. 25 "TVC Gas Generator Propellant," Report No. TP IM-109, Aerojet-General Corp., Sacramento, California, 22 October 1964.

Wing VI Plan.

A. 3. 1. 26 "TVC and RC Systems Storage Program," Report No. TP IM-108, Aerojet-General Corp., Sacramento, California, 22 October 1964.

Wing VI Plan.

A. 3. 1. 27 "Aft End Grain Measurement of Storage Motors," Report No. TP IM-105, Aerojet-General Corp., Sacramento, California, 11 August 1964.

Wing VI Plan.

A. 3. 1. 28 "Full Scale ES Motors," Report No. TP 662B, Aerojet-General Corp., Sacramento, California, 4 August 1964.

* Current AGC Test Plans are included in Program Planning (References A. 2. 6 and A. 2. 7.)

A. 3. 1 TEST PLANS (Continued)

Stage II (Continued)

A. 3. 1. 29 "Insulation Aging Program," Report No. TP IM-040B, Aerojet-General Corp., Sacramento, California, 27 March 1964.

Wing VI Plan.

A. 3. 1. 30 "Full Scale ES Motors," Report No. TP 620, revision 4, Aerojet-General Corp., Sacramento, California, 5 November 1963.

A. 3. 1. 31 "Detailed Component and Laboratory Aging Test Plan," Report No. TP 720, revision A, Change 1, Aerojet-General Corp., Sacramento, California, 20 September 1963.

A. 3. 1. 32 "Laboratory Aging Program for Wing VI Propellant," Report No. TP IM-032, Aerojet-General Corp., Sacramento, California, 1 August 1963.

A. 3. 1. 33 "Full Scale A-Motors," Report No. TP 598, revision 5, Aerojet-General Corp., Sacramento, California, 18 July 1963.

A. 3. 1. 34 "Detailed Component and Laboratory Aging Test Plan," Report No. TP 720, revision A, Aerojet-General Corp., Sacramento, California, 27 June 1963.

A. 3. 1. 35* "Detailed Component and Laboratory Aging Test Plan, Stage II," Report No. TP 720, Revision A, Aerojet-General Corp., Sacramento, California, 27 June 1963.

A. 3. 1. 36 "Laboratory Aging Program for Wing VI Propellant," Report No. TP IM-032, Aerojet-General Corp., Sacramento, California, 30 October 1962.

A. 3. 1. 37 "Full Scale Motors, Storage and Aging Program," Report No. TP IM-034, Aerojet-General Corp., Sacramento, California, 30 October 1962.

Wing VI Plan.

A. 3. 1. 38 "Insulation Aging Program," Report No. TP IM-040, Aerojet-General Corp., Sacramento, California, 30 October 1962.

Wing VI Plan.

A. 3. 1. 39 "Thrust Vector Control System Aging Program," Report No. TP IM-041, Aerojet-General Corp., Sacramento, California, 30 October 1962.

Wing VI Plan.

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*This reference inadvertantly duplicated ; see A. 3. 1. 34.

A. 3. 1 TEST PLANS (Continued)

Stage II (Continued)

A. 3. 1. 40 "Igniter Assembly Aging Program," Report No. TP IM-042, Aerojet-General Corp., Sacramento, California, 30 October 1962.

Wing VI Plan.

A. 3. 1. 41 "Detailed Component and Laboratory Aging Test Plan," Report No. TP 720, Change 1, Aerojet-General Corp., Sacramento, California, 5 September 1962.

A. 3. 1. 42 "Detailed Component and Laboratory Aging Test Plan," Report No. TP 720, revised, Aerojet-General Corp., Sacramento, California, 14 August 1962.

A. 3. 1. 43 "Full Scale A-Motors," Report No. TP 598, revision 4a, Aerojet-General Corp., Sacramento, California, 27 November 1961.

A. 3. 1. 44 "Full Scale ES Motors," Report No. TP 662, revision 2A, Aerojet-General Corp., Sacramento, California, 28 October 1961.

A. 3. 1. 45 "Detailed Component and Laboratory Aging Test Plan," Report No. TP 720, Aerojet-General Corp., Sacramento, California, 17 October 1961.

Stage III*

A. 3. 1. 46 "Master Test Plan Surveillance/Storage Program," Report No. MTO-101C, Hercules Powder Co., Magna, Utah, 31 March 1962.

A. 3. 1. 47 "Master Test Plan Surveillance/Storage Program," Report No. MTO-101B, Hercules Powder Co., Magna, Utah, November 1961.

A. 3. 1. 48 "Master Test Plan Surveillance/Storage Program," Report No. MTO-101A, Hercules Powder Co., Magna, Utah, 7 July 1961.

A. 3. 1. 49 "Master Test Plan Surveillance/Storage Program," Report No. MTO-101, Hercules Powder Co., Magna, Utah, March 1961.

*Current HPC test plans are included in program planning (References A. 2. 11-A. 2. 13).

A. 3. 1 TEST PLANS (Continued)

Propulsion Subsystems, General

A. 3. 1. 50 "Accelerated Test Plan, Phase 1, LGM-30 Wing I Test Data for February 1965," (First 200 blocks), OOAMA, Hill Air Force Base, Utah, 30 March 1965.

Miscellaneous

A. 3. 1. 51 "Test Directive for Project How Now Testing of Spin Rocket Motors, A/A44A-8 for MINUTEMAN RV System," Report No. M4-198-G, Ogden Air Material Area, Hill Air Force Base, Ogden, Utah, September 1964.

A. 3. 1. 52 "Test Directive for Project How Now Testing of Pitch Rocket Motors A/AA44A-7 for MINUTEMAN RV System," Report No. M4-199-G, Ogden Air Material Area, Hill Air Force Base, Ogden, Utah, September 1964.

A.3.2 TEST PROCEDURES

Stage I

A.3.2.1 "Obtaining Multiaxial Propellant Properties Using the Hollow Sphere Test MINUTEMAN Surveillance Program," Report No. TWR-1644, Thiokol Chemical Corp., Brigham City, Utah, 31 January 1966.

A.3.2.2 "Wing II Liner Bond Evaluation, MINUTEMAN Surveillance Program," Report No. TWR-1643, Thiokol Chemical Corp., Brigham City, Utah, 31 January 1966.

A.3.2.3 "Summary Report, Comparison of Thiokol Chemical Corp., Ogden Air Material Area, Laboratory Surveillance Tests," Report No. TWR 1645, 0317-22-0176, Thiokol Chemical Corp., Brigham City, Utah, January 1966.

A.3.2.4 "Comparison of Machine and Die-Cut JANAF Specimens," Report No. MQA22-63, Thiokol Chemical Corp., Brigham City, Utah, 27 January 1964.

Stage II

A.3.2.5 "Summary Report, Dynamic Test Program, MINUTEMAN Propellants," Report No. 0162-01DR-29, Aerojet-General Corp., Sacramento, California, 10 April 1964.

A comparative evaluation of several test methods for determining dynamic modulus of MINUTEMAN propellant.

Stage III

A.3.2.6 Ogden Air Material Area-Hercules Powder Co., Cooperative Test Program, Report No. 127/5/10-141, Hercules Powder Co., Magna, Utah, 9 November 1965.

A.3.2.7 "The Effect of Two Methods of Sample Preparation on the Propellant Material Properties," Report No. 127/5/10-35, Hercules Powder Co., Magna, Utah, 24 June 1964.

Describes the effect of dry and wet machining process on material properties of MINUTEMAN Stage III propellant.

A.3.2.8 "Case Bonding Physical Property Test Development," Report No. MTI-228, Hercules Powder Co., Magna, Utah, 22 July 1960.

A. 3. 2 TEST PROCEDURES (Continued)

Propulsion Subsustems, General

A. 3. 2. 9 "Hercules Cooperative Test Program," Summary Report, Ogden Air Material Area (AFLC), Hill Air Force Base, Ogden, Utah, 30 December 1965.

A. 3. 2. 10 "Ogden Air Material Area-Thiokol Chemical Corp., Cooperation Test Data," Ogden Air Material Area, Hill Air Force Base, Ogden, Utah, 30 June 1965.

A. 3. 2. 11 "Ogden Air Material Area-Aerojet-General Corp., Cooperative Test Data, Preliminary Report," Ogden Air Material Area, Hill Air Force Base, Ogden, Utah, 15 March 1965.

A. 3. 2. 12 "Cooperative Test Program on MINUTEMAN Propellant for the Surveillance Working Group," Report No. 6440-6002-TU 000 (Rough Draft), Space Technology Laboratories, 15 June 1964.

A. 3. 2. 13 "Approach to the Initiation of Comparative Uniaxial Tensile Testing for the MINUTEMAN Operational Surveillance Program," T.O. Report No. 6121-7692-TU000, Space Technology Laboratories, 31 October 1963.

Contains recommendations for standardizing the uniaxial tensile test for propellants and for reducing the data.

A. 3. 2. 14 "Guidelines for Revising Propellant Sampling Plan for the LGM-30 Weapon System Operational Surveillance Plan," T.O. Report No. 6440-6005-TU000, Space Technology Laboratories, 13 October 1963.

A. 3. 2. 15 "Results of MINUTEMAN Engine Contractor's 'Round Robin' Propellant Mechanical Properties Test," T.O. Report No. 6121-7244-KU000, Space Technology Laboratories, 26 July 1963.

Contains results of "Round Robin" tests on two types of propellant tests, i.e., stress relaxation and dynamic modulus.

A. 3. 2. 16 "Standard Operating Procedure for Radiographic Inspection of the MINUTEMAN Missile SM-80," SOP Number 204, Ogden Air Material Area, Hill Air Force Base, Ogden, Utah, 27 June 1962.

A.3.3 FAILURE CRITERIA

Stage I

A.3.3.1 "Test Plan for Analysis of Bond During Vertical Storage and Ignition Transient," Report No. TWR-712, Thiokol Chemical Corp., Brigham City, Utah, 21 August 1964.

A.3.3.2 "Test Plan for Aging Studies,Structural Analysis, and Failure Criteria, Wing II Storage, MINUTEMAN Motors," Report No. TWR-705, Thiokol Chemical Corp., Brigham City, Utah, 19 August 1964.

A.3.3.3 "Test Plan, MINUTEMAN Stage I Motor, Structural Analyses and Failure Criteria Development," (Preliminary Revision), Report No. TWR 712, Thiokol Chemical Corp., Brigham City, Utah, (undated).

Stage II

A.3.3.4 "Investigation of Propellant-Liner Bonds and Development of Failure Criteria for MINUTEMAN Wing II, Second Stage Propellant Liner Bond System," Report No. TM 231, Aerojet-General Corp., Sacramento, California, August 1964.

A.3.3.5 "Measurement of Propellant Failure Limits Under Various Test Conditions and Their Application to the Evaluation of MINUTEMAN Wing II, Second Stage Propellants," Report No. TM 232SRP, Aerojet-General Corp., Sacramento, California, August 1963.

Stage III

A.3.3.6 "Failure Criteria Surveillance Program — Further Development in Stress Analysis of the Aft Dome of MINUTEMAN Wing II Cases," Report No. 4, Hercules Powder Co., Magna, Utah, 13 August 1965.

A.3.3.7 "Failure Criteria Surveillance Program — Token Shear Specimen Testing," Report No. 5, Hercules Powder Co., Magna, Utah, 12 August 1965.

A.3.3.8 "High Rate Hydro Test of a MINUTEMAN Stage III Rocket Motor, Final Report," Report No. MTO-752-41, Hercules Powder Co., Magna, Utah, 29 April 1965.

A.3.3.9 M. C. Sharma and C.K. Lim, "Mechanical Properties of Solid Propellants for Combined States of Stresses of Various Temperatures," Report No. ABL/X-114, Hercules Powder Co., Cumberland, Maryland, September 1963.

A. 3. 3 FAILURE CRITERIA (Continued)

Propulsion Subsystems, General

A. 3. 3. 10 "Weapon System 133A and Weapon System 133B MINUTEMAN Propulsion Replacement Criteria," Report No. 4459-0108-TO-000, TRW Systems, April 1966.

A. 3. 3. 11 "MINUTEMAN Motor Storage Reliability Evaluation," TRW Systems Interoffice Memorandum, Report No. 65-9731. 5-203 4459-10, 27 December 1965.

Presents method for utilizing cumulative successful firing at various ages to evaluate age-reliability.

A. 3. 3. 12 "Proposed Reliability Demonstration Requirement and Current Status of the Wing I MINUTEMAN Full-Scale Motor Surveillance Program," Space Technology Laboratories Interoffice Memo, Report No. 63-9731-5-212, 31 December 1963.

A. 3. 3. 13 "Continuing Reliability Demonstration and Evaluation Program for Stage I MINUTEMAN Motors," Report No. 6120-J627-TC002, Space Technology Laboratories, April 1963.

A. 3. 3. 14 "Continuing Reliability Demonstration and Evaluation Program for Stage II MINUTEMAN Motors," Report No. 6120-J628-TC002, Space Technology Laboratories, April 1963.

A. 3. 3. 15 "Continuing Reliability Demonstration and Evaluation Program for Stage III, MINUTEMAN Motors," Report No. 6120-J629-TC002, Space Technology Laboratories, April 1963.

A.3.4 SERVICE LIFE ESTIMATION

Stage I

A.3.4.1 "Service Life Predictions, MINUTEMAN Stage I Motor Surveillance Program," Report No. TWR-1688, Thiokol Chemical Corp., Brigham City, Utah, 6 February 1966.

Retro and Tumble Motors

A.3.4.2 "MINUTEMAN Retro and Tumble Motors, Service Life of," Interoffice Memo 6650.05.65-1229, TRW Systems to BSRPQ 7 July 1965. (C)

Defines present service life and future requirements.

A.3.4.3 "Storage/Surveillance Program Summary Retro and Tumble Motors," Hercules Powder Co., Kenvil, New Jersey, 31 March 1965. (C)

Status report on program from November 1964 to March 1965, estimates service life of retro motor as 23 months demonstrated and 36 months predicted and of the tumble motor as 24 months demonstrated and 36 months predicted.

Propulsion Subsystems, General

A.3.4.4 "Service Life Estimate for MINUTEMAN Wings II through VI Propulsion Subsystems," Report No. 4459-0102-T7000, TRW Systems, 5 January 1966.

A.3.4.5 J.L. Meyrs and A.E. Lenehan, "MINUTEMAN Service Life Estimation," Report No. IOC 9733. 3-64-2-22, Space Technology Laboratories, Redondo Beach, California, 30 March 1964.

A.4 AGING PROGRAM RESULTS

A.4.1 MOTOR DATA BOOKS

Stage I

A.4.1.1 "Data Book for Stage I Rocket Motor, Wing VI, Section 3.0," Revision No. 0, Report No. TW-201-11-65, Thiokol Chemical Corp., Brigham City, Utah, September 1965.

Contains Wing VI Data.

A.4.1.2 "Weapon System 133A, M55A1 MINUTEMAN Data Book," Revision 3, Report No. TW-552-11-62, Thiokol Chemical Corp., Brigham City, Utah, December 1962.

Contains Wing II Data.

A.4.1.3 "Stage I MINUTEMAN Data Book, WS 133A," Revision E, Report No. TW-119-12-61, Thiokol Chemical Corp., Brigham City, Utah, 6 December 1961.

Contains Wing I Data.

Stage II

A.4.1.4 "Configuration Definition Report, Wing II, R&D Surveillance Motors," Report No. 0162-03ES-1, Aerojet-General Corp., Sacramento, California, April 1965.

A.4.1.5 "Stage II MINUTEMAN Wing VI Motor Data Book," Report No. GM-TR-0165-00478, Aerojet-General Corp., Sacramento, California, 1 August 1964.

A.4.1.6 "Configuration Definition Report, Wing I, R&D Surveillance Motors," Report No. 0162-01ES-1, Aerojet-General Corp., Sacramento, California 30 June 1964.

A.4.1.7 "Wing VI Storage Motor Configurations," Aerojet-General Corp., Drawing Nos. 383669, 369559, 369995, Aerojet-General Corp., Sacramento, California.

Stage III

A.4.1.8 "Data Book for Stage III Rocket Motor Wing VI," Report No. MTO-519-1, Hercules Powder Co., Magna, Utah, 5 January 1966.

A.4.1.9 "Data Book for Stage III Rocket Motor, Wing VI, Section 5.0," Revision No. 0, Report No. MTO-519-1, Hercules Powder Co., Magna, Utah, 5 January 1966.

A. 4. 1 MOTOR DATA BOOKS (Continued)

Stage III (Continued)

A. 4. 1. 10 "Data Book for Stage III Rocket Motor, Wings I, II, and IV," MTO-23-13, Hercules Powder Co., Magna, Utah, 7 October 1963.

Retro Tumble Motors

A. 4. 1. 11 "Model Specification Tumble Rocket Motor," SR9-HP-1, Operational (U) S-133-1010-1, Hercules Powder Co., Kenvil, New Jersey, 28 June 1963.

A.4.2 MOTOR DEVELOPMENT AND QUALIFICATION TEST REPORTS

Stage I

A.4.2.1 "Stage I, MINUTEMAN Production Motors, Weapon System 133A," Contract Status Report No. 265-6798, Thiokol Chemical Corp., Brigham City, Utah, December 1964. (C)

Discusses further laboratory aging of propellants, liners, and insulations. No appreciable degradation noted. All specimens available to extend program to 10 years fabricated and stored.

A.4.2.2 "Qualification Test Plan, MINUTEMAN Missile KR 80000-08, Standardized Igniter Safety and Arming Device," Report No. TWR-649, Thiokol Chemical Corp., Brigham City, Utah, 10 September 1964.

A.4.2.3 "Weapon System 133B, Prequalification Test Plan, MINUTEMAN Missile 7U32257, Standardized Igniter Safety and Arming Device (Prototype)," Report No. TWR-633, Thiokol Chemical Corp., Brigham City, Utah, 20 August 1964.

A.4.2.4 "Final Report. Qualification Test Program for M55E1 Wing II Rocket Motors (Amendment I)," Report No. TWR-445, TW-279-8-63, Thiokol Chemical Corp., Brigham City, Utah, 15 March 1964.

A.4.2.5 "Final Test Results, Stage I MINUTEMAN Nozzle," ARDE-Portland, Inc. S/N 5153 TU-109.92, Report No. TWR-533, TW-562-12-63, Thiokol Chemical Corp., Brigham City, Utah, December 1963.

A.4.2.6 "Final Report, Qualification Test Program for M55E1 Wing II Rocket Motors," Report No. TW-279-8-63, TW-280-8-63, TWR-445, Thiokol Chemical Corp., Brigham City, Utah, 13 September 1963.

A.4.2.7 "Improved Stage I MINUTEMAN Program," Report Nos. TW77-7-62; TW467-7-62: TW-622-8-62, Thiokol Chemical Corp., Brigham City, Utah, May-August 1962. (C)

Reports propellant aging studies; catalyst effects, better accelerated aging characteristics.

A.4.2.8 "Program Progress Weapon System 133A," Contract AF33 (600)-36514, Quarterly Reports beginning July 1961, Thiokol Chemical Corp., Brigham City, Utah.

A.4.2.9 "Final Report, Preliminary Flight Rating Test Program for XM-55 Rocket Engine," TW-773-5-61, Thiokol Chemical Corp., Brigham City, Utah, May 1961.

A.4.2 MOTOR DEVELOPMENT AND QUALIFICATION TEST REPORTS (Continued)

Stage I (Continued)

A.4.2.10 "Weapon System 133A, Final Report, Qualification Test Program for M55E1 Wing II Rocket Motor Appendices," TW-280-8-63, TWR-445, Thiokol Chemical Corp., Brigham City, Utah.

A.4.2.11 "Weapon System 133A, Final Report, Qualification Test Program for M55E1 Wing II Rocket Motors," TW-279-8-63, TWR-445, Thiokol Chemical Corp., Brigham City, Utah.

Stage II

A.4.2.12 "Stage II MINUTEMAN Motor Wing VI Qualification Test Program," Report No. 0162-06TDR-8, Aerojet-General Corp., Sacramento, California, 12 October 1965.

A.4.2.13 "Weapon System 133B, Development and Fabrication of Solid-Propellant Rocket Motors for the Second Stage of the Wing VI MINUTEMAN Missile," Report No. 0162-026Q-8, Aerojet-General Corp., Sacramento, California, 30 May 1965.

A.4.2.14 "Technical Direction Meeting, MINUTEMAN Second-Stage Motor, Wing VI," Aerojet-General Corp., Sacramento, California, 17 February 1965.

Pages 21-52 summarize storage program.

A.4.2.15 "Final Report, Development of Solid Propellant Rocket Motors for the Second Stage of the MINUTEMAN Missile," Report No. 0162-01TDR-7, Aerojet-General Corp., Sacramento, California, 29 June 1964.

A.4.2.16 "Reliability Refiring Analysis of Extended Storage Motors 44ES-1 through -14 and -14A," (44FTM-421B), AD-452 199, Aerojet-General Corp., Sacramento, California, April 1963. (C)

Describes modifications made to second stage Wing I motors for the storage program.

A.4.2.17 "Development of an Improved Solid Propellant Rocket Motor for Second Stage of the MINUTEMAN Missile," Final Report No. 0162-02TDR-1, Aerojet-General Corp., Sacramento, California, 15 October 1962.

A.4.2.18 "Development of Solid-Propellant Rocket Motors for the Second Stage of the MINUTEMAN Missile, Weapon System 133A," Program Progress Report No. 0162-01M-26, 51 pp. Aerojet-General Corp., Sacramento, California, 20 August 1962. (C)

Discusses development surveillance. Reports on propellant aging.

A.4.2 MOTOR DEVELOPMENT AND QUALIFICATION TEST REPORTS (Continued)

Stage II (Continued)

A.4.2.19 "Weapon System 133A, Development of an Improved Solid Propellant Rocket Motor for the Second Stage of the MINUTEMAN Missile," Program Progress Report No. 0162-02M-4, Aerojet-General Corp., Sacramento, California, June 1962. (C)

Reports on accelerated aging studies of MAPO/CTPB propellants. Postulates that the P-N bond is hydrolytically broken. Use of desiccant in the propellant appears to prevent softening at high temperatures.

Stage II - Monthly Progress Reports

A.4.2.20 "MINUTEMAN Second Stage Monthly Progress Report," Report No. 0162-01M-32, Aerojet-General Corp., Sacramento, California, 20 October 1962.

A.4.2.21 "MINUTEMAN Second Stage Monthly Progress Report," Report No. 0162-01M-31, Aerojet-General Corp., Sacramento, California, 20 September 1962.

A.4.2.22 "MINUTEMAN Second Stage Monthly Progress Report," Report No. 0162-01M-30, Aerojet-General Corp., Sacramento, California, 20 August 1962.

A.4.2.23 "MINUTEMAN Second Stage Monthly Progress Report," Report No. 0162-01M-29, Aerojet-General Corp., Sacramento, California, 20 July 1962.

A.4.2.24 "MINUTEMAN Second Stage Monthly Progress Report," Report No. 0162-01M-28, Aerojet-General Corp., Sacramento, California, 20 June 1962.

A.4.2.25 "MINUTEMAN Second Stage Monthly Progress Report," Report No. 0162-01M-27, Aerojet-General Corp., Sacramento, California, 20 May 1962.

A.4.2.26 "MINUTEMAN Second Stage Monthly Progress Report," Report No. 0162-01M-26, Aerojet-General Corp., Sacramento, California, 20 April 1962.

A.4.2.27 "MINUTEMAN Second Stage Monthly Progress Report," Report No. 0162-01M-25, Aerojet-General Corp., Sacramento, California, 20 March 1962.

A.4.2.28 "MINUTEMAN Second Stage Monthly Progress Report," Report No. 0162-01M-24, Aerojet-General Corp., Sacramento, California. 20 February 1962.

A.4.2 MOTOR DEVELOPMENT AND QUALIFICATION TEST REPORTS (Continued)

Stage II - Monthly Progress Reports (Continued)

A.4.2.29 "MINUTEMAN Second Stage Monthly Progress Report," Report No. 0162-01M-23, Aerojet-General Corp., Sacramento, California, 20 January 1962.

A.4.2.30 "MINUTEMAN Second Stage Monthly Progress Report," Report No. 0162-01M-22, Aerojet-General Corp., Sacramento, California 20 December 1961.

A.4.2.31 "MINUTEMAN Second Stage Monthly Progress Report," Report No. 0162-01M-21, Aerojet-General Corp., Sacramento, California, 20 November 1961.

A.4.2.32 "MINUTEMAN Second Stage Monthly Progress Report," Report No. 0162-01M-20, Aerojet-General Corp., Sacramento, California, 20 October 1961.

A.4.2.33 "MINUTEMAN Second Stage Monthly Progress Report," Report No. 0162-01M-19, Aerojet-General Corp., Sacramento, California, 20 September 1961.

A.4.2.34 "MINUTEMAN Second Stage Monthly Progress Report," Report No. 0162-01M-18, Aerojet-General Corp., Sacramento, California, 20 August 1961.

Stage II - Quarterly Progress Reports

A.4.2.35 "Development of a Solid Propellant Rocket Motor, Second Stage, Wing VI MINUTEMAN Missile," Report No. 0162-026Q-7, Aerojet-General Corp., Sacramento, California, 2 March 1965.

A.4.2.36 "Development of a Solid Propellant Rocket Motor, Second Stage, Wing VI MINUTEMAN Missile," Report No. 0162-026Q-6, Aerojet-General Corp., Sacramento, California, 30 November 1964.

A.4.2.37 "Development of a Solid Propellant Rocket Motor, Second Stage, Wing VI MINUTEMAN Missile," Report No. 0162-026Q-5, Aerojet-General Corp., Sacramento, California 30 August 1964.

A.4.2.38 "Development of a Solid Propellant Rocket Motor, Second Stage, Wing VI MINUTEMAN Missile," Report No. 0162-026Q-4, Aerojet-General Corp., Sacramento, California, 30 May 1964.

A. 4. 2 MOTOR DEVELOPMENT AND QUALIFICATION TEST REPORTS (Continued)

Stage II - Quarterly Progress Reports (Continued)

A. 4. 2. 39 "MINUTEMAN Second Stage Quarterly Progress Report," Report No. 0162-01Q-12, Aerojet-General Corp., Sacramento, California, 30 April 1964.

A. 4. 2. 40 "Development of a Solid Propellant Rocket Motor, Second Stage, Wing VI MINUTEMAN Missile," Report No. 0162--26A-3, Aerojet-General Corp., Sacramento, California, 1 March 1964.

A. 4. 2. 41 "MINUTEMAN Second Stage Quarterly Progress Report," Report No. 0162-01Q-11, Aerojet-General Corp., Sacramento, California, 30 January 1964.

A. 4. 3. 42 "Development of a Solid Propellant Rocket Motor, Second Stage, Wing VI MINUTEMAN Missile," Report No. 0162-026Q-2, Aerojet-General Corp., Sacramento, California, 30 November 1963.

A. 4. 2. 43 "Development of a Solid Propellant Rocket Motor, Second Stage, Wing VI MINUTEMAN Missile," Report No. 0162-026Q-1, Aerojet-General Corp., Sacramento, California, 30 August 1963.

A. 4. 2. 44 "MINUTEMAN Second Stage Quarterly Progress Report," Report No. 0162-01Q-10, Aerojet-General Corp., Sacramento, California, 30 October 1963.

A. 4. 2. 45 "MINUTEMAN Second Stage Quarterly Progress Report," Report No. 0162-01Q-9, Aerojet-General Corp., Sacramento, California, 30 July 1963.

A. 4. 2. 46 "MINUTEMAN Second Stage Quarterly Progress Report," Report No. 0162-01Q-8, Aerojet-General Corp., Sacramento, California, 30 April 1963.

A. 4. 2. 47 "MINUTEMAN Second Stage Quarterly Progress Report," Report No. 0162-01Q-7, Aerojet-General Corp., Sacramento, California, 30 January 1963.

A. 4. 2. 48 "MINUTEMAN Second Stage Quarterly Progress Report," Report No. 0162-01Q-6, Aerojet-General Corp., Sacramento, California, 30 July 1961.

A. 4. 2. 49 "MINUTEMAN Second Stage Quarterly Progress Report," Report No. 0162-01Q-5, Aerojet-General Corp., Sacramento, California, 30 April 1961.

A.4.2 MOTOR DEVELOPMENT AND QUALIFICATION TEST REPORTS (Continued)

Stage II - Quarterly Progress Reports (Continued)

A.4.2.50 "MINUTEMAN Second Stage Quarterly Progress Report," Report No. 0162-01Q-4, Aerojet-General Corp., Sacramento, California, 30 January 1961.

A.4.2.51 "MINUTEMAN Second Stage Quarterly Progress Report," Report No. 0162-01Q-3, Aerojet-General Corp., Sacramento, California, 31 October 1960.

A.4.2.52 "MINUTEMAN Second Stage Quarterly Progress Report," Report No. 0162-01Q-2, Aerojet-General Corp., Sacramento, California, 30 July 1960.

Stage III

A.4.2.53 "Program Plan for Operational Reliability Improvement," MTO-162-237-3, Hercules Powder Co., Magna, Utah, June 1965.

A.4.2.54 "Final Report, Exhibits D, G, and H to MINUTEMAN Contract AF-04 (647)-243, (Wing II - V)," Report No. MTD-19, Hercules Powder Co., Magna, Utah 23 April 1964. (C)

Volume I - Summary Volume II - Component Appendix A
Volume V - Propellant Volume VI - Motors and Drawings

A.4.2.55 "Program Plan for Operational Reliability Improvement," Report No. MTO-162-237-2, Hercules Powder Co., Magna, Utah, 6 March 1965.

A.4.2.56 "Final Report, Quality Assurance Test No. V-QA-41 (Ground Level Test) M57A1 Operational Rocket Motor," Report No. MTO-734-42, Hercules Powder Co., Magna, Utah, 6 January 1965.

A.4.2.57 "Program Plan, Wing VI, Preproduction Motors," MTO-162-237-1, Hercules Powder Co., Magna, Utah, January 1965.

A.4.2.58 "Program Plan, Aft Dome Corrective Action for New Production Motors," MTO 162-237, Hercules Powder Co., Magna, Utah, 8 December 1964.

A.4.2.59 "Final Report of the Transportation and Handling Program for the Stage III MINUTEMAN Motor Weapon System 133A," Report No. TDI-MTD-21, Hercules Powder Co., Magna, Utah, 30 June 1964. (C)

Reports on successful firing of 5 full-scale motors; gives propellant properties.

A. 4. 2 MOTOR DEVELOPMENT AND QUALIFICATION TEST REPORTS (Continued)

Stage III (Continued)

A. 4. 2. 60 "MINUTEMAN Program, Wing II Qualification Testing, Summary Final Report, Weapon System 133A," Report No. MTD-15, Hercules Powder Co., Magna, Utah, 31 January 1964.

A. 4. 2. 61 "Exhibit B, Final Report of Continued Research and Development Program Through Flight And Qualification Tests of MINUTEMAN, Stage III Rocket Motor," Hercules Powder Co., Magna, Utah, 29 April 1963.

Cover 1960-1962 period; gives evaluation of the Wing I motor.

A. 4. 2. 62 "MINUTEMAN Program, Wing I Qualification Testing, Summary Final Report, Weapon System 133A," Report No. MTD-11, Hercules Powder Co., Magna, Utah, January 1963.

A. 4. 2. 63 "MINUTEMAN Program, Wing I Qualification Testing, Summary Final Report (Preliminary)," Report No. MTD-11, Hercules Powder Co., Magna, Utah, January 1963. (C)

A. 4. 2. 64 "MINUTEMAN Program, Exhibit "A", Final Rep[illegible] Rocket Motor XM-57, Weapon System 133A MINUTEMAN Stage III," Report No. MTD-7, Hercules Powder Co., Magna, Utah, September 1962. (C)

R&D Final Report includes plan for aging of two full-scale motors, 60° and 100° F.

A. 4. 2. 65 "MINUTEMAN Stage III, Weapon System 133A, Quarterly Progress Report No. MCS-62," Hercules Powder Co., Magna, Utah, October-December 1960. (C)

Discusses surveillance firings of 40-pound charge motors. No detectable change in propellant data after 3 to 9 months storage at 60° or 100° F. Preliminary tests of 828/CL resin system showed no degradation [illegible] r a 12-week humidity test. Reports effects of ag[illegible] up to 6 months on tensile strength of several bonding systems.

A. 4. 2. 66 "MINUTEMAN Stage III, Weapon System 133A, Quarterly Progress Report No. MCS-54," Hercules Powder Co., Magna, Utah, July-September [illegible]0. (C)

Results of firing first five 40-pound charge surveillance motors after storage of [illegible] 9 months compared with firing unaged motors.

A. 4. 2 MOTOR DEVELOPMENT AND QUALIFICATION TEST REPORTS (Continued)

Stage III (Continued)

A. 4. 2. 67 "MINUTEMAN Stage III, Weapon System 133A, Quarterly Progress Report No. MCS-51," Hercules Powder Co., Magna, Utah, April-June 1960. (C)

Revised surveillance program plan covering a storage program of 46 full-scale units is attached to report. Statistical design project concerns computing all possible outcomes of a firing.

Retro and Tumble Motors

A. 4. 2. 68 "Final Report, Qualification Test Program, Tumble Rocket Motor, SR9-HP-1, Weapon System 133A," Report No. K-35/MR-300X-14, Hercules Powder Co., Kenvil, New Jersey, 31 March 1964. (C)

A. 4. 2. 69 "Final Report on Research and Development of the Retro and Tumble Rocket Motors," Report No. K-35/MR-100-5, Hercules Powder Co., Kenvil, New Jersey, 28 February 1964. (C)

A. 4. 2. 70 "Final Report, Wing II MINUTEMAN Reverse Thrust System, Weapon System 133A," Report No. K-35/MR-100-5, Hercules Powder Co., Kenvil, New Jersey, 28 February 1964. (C)

Summarizes R&D on the retro and tumble motors in the period 1 September 1961 to 31 January 1964, including motor description and bibliography.

A. 4. 2. 71 "Final Report, Qualification Test Program, Retro Rocket Motor (SR11-HP-1)," Report No. K-35/MR-300X-12, Hercules Powder Co., Kenvil, New Jersey, 7 February 1964. (C)

Propulsion Subsystems, General

A. 4. 2. 72 "Qualification Test Requirements for Retro and Pitch Rockets," Revision 2, STL 6120-6862-DC002, 10 July 1962.

A. 4 73 "Qualification Test Requirements for the MINUTEM... Engine Ordnance Subsystems (Ignition, Destructor, and Th... t Termination)," G. M. 61-7650. 2-1002, Space Technology Laboratory 16 February 1962.

A. 4. 3 SPECIAL INVESTIGATIONS

Stage I

A. 4. 3. 1 "Final Report, Contamination Studies on Safety and Arming Devices," Report No. ODR 64-4, Thiokol Chemical Corp., Brigham City, Utah, 21 January 1964.

Stage II

A. 4. 3. 2 "Summary of Test Data for Wings II (IV) Second Stage Low Modulus Propellant," OOAMA, Hill Air Force Base, Utah, November 1964.

A. 4. 3. 3 "Final Report, Failure Investigation of Wing II, Second Stage Motor 44QT-209," Report No. 0162-01DR-37, Aerojet-General Corp., Sacramento, California, 29 June 1964.

A. 4. 3. 4 "Static Test Firing of Second-Stage MINUTEMAN Motor 44FW-93," Report No. TR434-93, Aerojet-General Corp., Sacramento, California, 21 October 1962.

A. 4. 3. 5 "Static Test Firing of Second-Stage MINUTEMAN Motor 44QT-16," Report No. 0162-01TR-QT-16, Aerojet-General Corp., Sacramento, California, 23 September 1962.

A. 4. 3. 6 "Static Test Firing of Second-Stage MINUTEMAN Motor 44QT-18," Report No. 0162-01TR-QT-18, Aerojet-General Corp., Sacramento, California, 29 July 1962.

A. 4. 3. 7 "Static Test Firing of Second-Stage MINUTEMAN Motor 44QT-15," Report No. 0162-01TR-QT-15, Aerojet-General Corp., Sacramento, California, 22 June 1962.

A. 4. 3. 8 "Static Test Firing of Second-Stage MINUTEMAN Engine 44FW-13," Report No. TR434-13, Aerojet-General Corp., Sacramento, California, 25 May 1961.

A. 4. 3. 9 "Final Report Static Test Firing of Second-Stage MINUTEMAN Engine 44ME-1," Test Report No. 0162-01TR-ME-1, Aerojet-General Corp., Sacramento, California, 5 May 1961.

St III

A. 4. 3. 10 "Investigation of Anomalous Aft Dome Insulator Erosion in the M57A1 Rocket Motor," Report No. MTO-162-251, Hercules Powder Co., Magna, Utah, 16 September 1965. (C)

A. 4. 3. 11 "Investigation of Anomalous Aft Dome Insulator Erosion in the M57A1 Rocket Motor, Part B--Subscale and Laboratory Tests and Data Review, Task I, Subscale Material Testing Final Report," Report No. MTO-162-250, Hercules Powder Co., Magna, Utah, 16 September 1965. (C)

A.4.3 SPECIAL INVESTIGATIONS (Continued)

Stage III (Continued)

Discusses erosive laboratory testing of insulators using rocket motor heat source.

A.4.3.12 "Final Report for Ignition Evaluation Program Test 5-10-43," Report No. MTO-164-239, Hercules Powder Co., Magna, Utah, 15 July 1965. (C)

Tests water exposure effect on Stage III; ignition was low pressure and long burning.

A.4.3.13 "MINUTEMAN Production Support Program—Glass Roving Literature Survey," Report No. 127/a/8-205, Hercules Powder Co., Magna, Utah, 10 June 1965.

A.4.3.14 "Summary Final Report, Cracked Nozzle Flange Extension for Firings 5-10-35, 5-10-40, and 5-10-41," Report No. MTO-16‹ 228, Hercules Powder Co., Magna, Utah, 26 February 1965.

A.4.3.15 Minutes c Program Review Meeting, "Investigation of Anomalous ^ · · I·,me Erosion," Held 11 November 1964 at Baccku s W Report No. 127/2/7-133, Hercules Powder Co., Magna, U..., 18 December 1964.

A.4.3.16 "Program Plan, Aft Dome Corrective Action for New Production Motors," Report No. MTO-162-237, Hercules Powder Co., Magna, Utah, 8 December 1964.

A.4.3.17 "Program Plan for Combined Full-Scale Firing for Evaluation of Aft Dome Erosion Exundate, Seam Sealing Replacement," TRW Nozzles, and Cracked Nozzle Flanges," Report No. MTO-198-75, Hercules Powder Co., Magna, Utah, 2 December 1964.

A.4.3.18 "Final Summary Report, Partial Burn Failure Demonstration Motors, 5-10-21 and 5-10-25," Report No. MTO-164-218, Hercules Powder Co., Magna, Utah, 23 November 1964. (C)

Failure of aft boot bond causes gas flow to erode boot, exposing additional propellant. Partial burn also revealed that the forward end had not ignited after 3.5 sec.

A.4.3.19 "Bonding Properties of the Transition Layer," Report No. HPC-050-15-1-20-IIIF, Hercules Powder Co., Magna, Utah, 30 October 1964.

A.‹.3.20 "Final Report, Failure Diagnosis Program," Report No. MTO-164 (1)-218-2, Hercules Powder Co., Magna, Utah 27 October 1964.

A. 4. 3 SPECIAL INVESTIGATIONS (Continued)

Stage III (Continued)

A. 4. 3. 21 "Phase I, Final Report, Investigation of Liquid Formation in the Third-Stage MINUTEMAN Motor," Report No. MTO-198-68, Weapon System 133A, Hercules Powder Co., Magna, Utah, August 1964.

A. 4. 3. 22 "Preliminary Program Plan for Development and Qualification of Substitutes for Fuller Co. Aircraft, Seam Sealing Compound," Report No. MTO-270/2/3-481, Hercules Powder Co., Magna, Utah, 1 July 1964.

A. 4. 3. 23 "A Study of Environmental Storage Effects on the Buckling Strength of Spiralloy, Weapon System [illegible]A, MINUTEMAN Stage III," Repo[illegible] No. MTO 125, Herc[illegible]s Powder Co., Magna, Utah, Ju[illegible]y 1964.

A. 4. 3. 24 "Final Repor[illegible] [illegible]ging of Raceway A[illegible]sive," R[illegible]port No. MTO 258-7, [illegible]rcules Powder Co., [illegible]agna, U[illegible], 20 May 1964.

Describe[illegible] [illegible]esults obtained in evaluation o[illegible] Armstrong A12T as a[illegible]esive bonding agent for rac[illegible]ay and Stage III MINUTEMAN motor.

A. 4. 3. 25 "Insulator Surface Contamination Elimination Study, Final Report," Report No. HPC-050-15-1-20-1F, Hercules Powder Co., Magna, Utah, 1 May 1964.

A. 4. 3. 26 "Detailed Program Plan, Investigation of Liquid Formation in Stage III MINUTEMAN Motor," Report No. M[illegible]-198-64, Hercules Powder Co., Magna, Utah, 14 April 1964.

A. 4. 3. 27 "Test Plan for Adhesive Aging Properties Evaluation," Report No. MTO 852-6, Hercules Powder Co., Magna, Utah, 16 March 1964.

Describes program plan for evaluation of aging properties of Armstrong A12T and Shell Epon 937 epoxy adhesives.

A. 4. 3. 28 "Bonding Properties of the Insulator-Insulator," Report No. HPC-050-15-1-20-IIF, Hercules Powder Co., Magna, Utah, 15 February 1964.

A. 4. 3. 29 "Final Report, Bonding Properties of the Insulator-Insulator (Buna S) in the Stage III MINUTEMAN Motor," Report No. HPC-050-15-1-20-IIF, Hercules Powder Co., Magna, Utah, 15 February 1964.

A.4.3 SPECIAL INVESTIGATIONS (Continued)

Stage III (Continued)

A.4.3.30 "Thrust Termination Frangible Sector Clip Breakage Problem," Report No. MTO-269-53, Hercules Powder Co., Magna, Utah, 13 December 1963.

A.4.3.31 "History of Ozone Cracking in Buna S Rubber (Wing II Internal Insulation)," Report No. MTO-269-39, Hercules Powder Co., Magna, Utah, September 1963.

A.4.3.32 "Reliability and Failure Report, Weapon System 133A, MINUTEMAN Stage III," Report No. MTO 22 200-11, Hercules Powder Co., Magna, Utah, July 1962.

A.4.3.33 "Study to Determine the Penetration of Casting Solvent into Epoxy Barrier Coatings," Report No. MTO-197, Hercules Powder Co., Magna, Utah, September 1961.

A.4.3.34 "Third Stage Firing, FSU-2-1-2," Report No. MTO-164-10, Hercules Powder Co., Magna, Utah, 30 June 1961.

Concerns nozzle port.

A.4.3.35 "Third Stage Firing, FSU-CD-18," Report No. MTO-170, Hercules Powder Co., Magna, Utah, 24 April 1961. (C)

Discusses hangfire.

A.4.3.36 "Third Stage Firing, FSU-CD-4," Hercules Powder Co., Magna, Utah, 19 November 1960.

Concerns case burnthrough (insulation).

A.4.3.37 "Third-Stage Firing, FSU-T-271-N (CD-1)," Report No. MT1-376, Hercules Powder Co., Magna, Utah, 17 October 1960. (C)

Discusses nozzle burnthrough.

A.4.3.38 "Investigation of Anomalous Aft Dome Insulator Erosion in the MS7A1/Rocket Motor, Part B—Subscale and Laboratory Tests and Data Review," Report No. MTO-162-252, Hercules Powder Co., Magna, Utah, 16 September.

Evaluates insulation-to-case bonding agents.

Retro and Tumble Motors

A.4.3.39 "Technical Direction Meeting, N[illegible] Retro and Tumble Rocket Motor, Wing VI, Reverse [illegible]st System," Report No. MTO-470-70, Hercules Powder Co., Kenvil, New Jersey, 1 June 1965.

A. 4. 3 SPECIAL INVESTIGATIONS (Continued)

Stage III (Continued)

A. 4. 3. 40 "Wing II, MINUTEMAN Reverse Thrust System MTO-470-66," Report No. 66, Technical Direction Meeting, Hercules Powder Co., Kenvil, New Jersey, 10 December 1964.

A. 4. 3. 41 "Wing II, MINUTEMAN Reserve Thrust System MTI-470-64," vol. II, Report No. 64, Technical Direction Meeting, Hercules Powder Co., Kenvil, New Jersey, 3 September 1964.

A. 4. 3. 42 "Detailed Program Plan, Retro and Tumble Motor Aging Anomaly Analysis," Report No. K-50-51/RTC-548, Hercules Powder Co., Kenvil, New Jersey, 31 July 1964.

A. 4. 3. 43 "Failure Analysis for Firings R-501F, R-506F, R-507F, R-510F, R-512F, R-514F, R-515F, and R-516F—Retro Tumble," Report No. K-35/MC-1272, Hercules Powder Co., Kenvil, New Jersey, 22 November 1963.

A. 4. 3. 44 "Environmental Aging Study On HTS—Finished S-994 Glass," Report No. 1/1/41-99, Hercules Powder Co., Kenvil, New Jersey, 31 October 1963.

A. 4. 3. 45 "Failure Analysis, R-514F," Report No. K-35/MC-1160, Hercules Powder Co., Kenvil, New Jersey, 4 September 1963. (C)

Investigates long burning time.

A. 4. 3. 46 "Failure Analysis, R-508F," Report No. K-35/MC-1064, Hercules Powder Co., Kenvil, New Jersey, 25 July 1963. (C)

Analyzes bond failure between aft insulator and propellant grain.

A. 4. 3. 47 "Dynamar Surveillance Test Results Retro and Tumble Rockets," Report No. K-35/MC-440, Hercules Powder Co., Kenvil, New Jersey, 5 November 1962. (C)

Study of NG absorption, elevated temperature bonding and ballistic performance of retro motors; impulse decreases; burnthrough at aft adapter; tailoff increases.

A.4.4 SURVEILLANCE WORKING GROUP MEETINGS

A.4.4.1 "Minutes of the Weapon System 133 MINUTEMAN Propulsion Surveillance Working Group Meeting," Report No. 4459-0105-TO 000, TRW Systems, 10 February 1966.

A.4.4.2 "Minutes of the Weapon System 133 MINUTEMAN Propulsion Surveillance Working Group Meetings, 9 and 10 November 1965," Report No. 4459-010-TO 000, TRW Systems, 10 November 1965.

A.4.4.3 "Minutes of the MINUTEMAN and Titan II Ordnance Surveillance Testing Programs Meeting held at OOAMA," 13-15 April 1965, OOAMA, 27 May 1965.

A.4.4.4 "Minutes of the Weapon System 133 MINUTEMAN Propulsion Surveillance Working Group Meetings, 1 and 2 April 1965," Report No. 6650-08-65-1427, Space Technology Laboratory, 19 May 1965.

A.4.4.5 "Minutes and Action Items from the 23-24 November 1964 MINUTEMAN Propulsion Surveillance Working Group Meeting" Report No. 6650.03-65-007K, Space Technology Laboratory, 24 November 1964.

A.4.4.6 [illegible] ion Items from the 23-26 June 1964 [illegible] MAN [illegible] pulsion Surveillance Working Group [illegible] Re[illegible] N[illegible] 6650.03-64-076K, Space Technology [illegible] 28 [illegible] ne 1964.

A.4.4.7 [illegible] Min[illegible] Items of the MINUTEMAN Propulsion Surve[illegible]nce W[illegible] Group Meeting," Report No. 6650.04-64 [illegible] nology Labora[illegible]ry, 19 February 1964.

A.4.4.8 "Minutes a[illegible] ion Items of the MINUTEMAN Propulsion Surveillance Working Group Meeting," Report No. 6650.04-613, Space Technology Laboratory, 9 January 1964.

A.4.4.9 "Minutes and Action Items of the MINUTEMAN Propulsion Surveillance Working Group Meeting," Report No. 6650.04-63-684, Space Technology Laboratory, 2 December 1963.

A.4.4.10 "Minutes and Action Items of the MINUTEMAN Propulsion Surveillance Working Group Meeting," Report No. 6650.04-63-628, Space Technology Laboratory, 28 February 1963.

A.4.4.11 "Minutes and Action Items of the MINUTEMAN Propulsion Surveillance Working Group Meeting," Report No. 6650.04-63-604, Space Technology Laboratory, 10 January 1963.

A.4.4.12 "MINUTEMAN Surveillance Working Group Meeting Minutes," Report No. 62-9731.5-808, Space Technology Laboratory, 23 August 1962.

A.4.4 SURVEILLANCE WORKING GROUP MEETINGS (Continued)

A.4.4.13 "MINUTEMAN Surveillance Working Group Minutes," Report No. 62-9731.5-1055, Space Technology Laboratory, 29 June 1962.

A.4.4.14 "MINUTEMAN Surveillance Working Group Meeting Minutes," Report No. 6120-7393-DC000, Space Technology Laboratory, 15 February 1962.

A.4.5 PROGRESS REPORTS ON MINUTEMAN AGING PROGRAM

Stage I

A.4.5.1 "MINUTEMAN Stage I Motor Surveillance Quarterly Report," Report No. TWR-1649, TAI-110-1-6, Thiokol Chemical Corp., Brigham City, Utah, 1 October thru 31 December 1965.

A.4.5.2 "Quarterly Report Surveillance Program for Stage I MINUTEMAN Rocket Motor, Third Quarter 1965," Thiokol Chemical Corp., Brigham City, Utah, 9-10 November 1965.

A.4.5.3 "MINUTEMAN Stage I Motor Surveillance Quarterly Report," Report No. TWR-1503, TW-12-11-65, Thiokol Chemical Corp., Brigham City, Utah, 1 July thru 30 September 1965.

A.4.5.4 "MINUTEMAN Stage I Motor Surveillance Quarterly Report," Report No. TWR-1218, TW-33-8-65, Thiokol Chemical Corp., Brigham City, Utah, 1 April thru 30 June 1965.

A.4.5.5 "1965 First Quarterly Report Demonstrated and Predicted Storage Life Stage I MINUTEMAN Rocket Motor," Report No. TWR-960, TW-107-5-65, Thiokol Chemical Corp., Brigham City, Utah, 10 May 1965.

A.4.5.6 "1964 Annual Report Demonstrated and Predicted Storage Life Stage I MINUTEMAN Rocket Motor," Report No. TWR-875, TW-184-3-65, Thiokol Chemical Corp., Brigham City, Utah, 17 March 1965.

A.4.5.7 "Stage I MINUTEMAN Ordnance Storage Program, 1964 Annual Report," Report No. TWR-841, 1B-65-45, Thiokol Chemical Corp., Brigham City, Utah 15 January 1965.

A.4.5.8 "1964 3rd Quarterly Report, Demonstrated and Predicted Stroage Life for Full-Scale, Flight-Weight Stage I MINUTEMAN Rocket Motor," Report No. TWR-786, TW-319-11-64, Thiokol Chemical Corp., Brigham City, Utah, 27 November 1964.

A.4.5.9 "Quarterly Report Demonstrated and Predicted Storage Life for Full-Scale, Flight-Weight Stage I MINUTEMAN Rocket Motors," Report No. TWR-631, TW-581- 7-64, Thiokol Chemical Corp., Brigham City, Utah, 25 July 1964.

A.4.5.10 "Long-Term Storage and Accelerated Aging, Summary Report, Volume I, Stage I, MINUTEMAN Motor Wings I and II, Main Case and Aft Closure Propellants," Report No. 664-4963, Thiokol Chemical Corp., Brigham City, Utah, 22 June 1964.

A.4.5 PROGRESS REPORTS ON MINUTEMAN AGING PROGRAM (Continued)

Stage I (Continued)

A.4.5.11 "Quarterly Report, Demonstrated and Predicted Storage Life for Full-Scale, Flight-Weight Stage I MINUTEMAN Rocket Motors," Report No. TWR-580, Amendment 1, Thiokol Chemical Corp., Brigham City, Utah, 20 April 1964.

A.4.5.12 "Quarterly Report, Demonstrated and Predicted Storage Life for Full-Scale, Flight-Weight Stage I MINUTEMAN Rocket Motors," Report No. TWR-580, TW-88-4-64, Thiokol Chemical Corp., Brigham City, Utah, 15 April 1964.

A.4.5.13 "Annual Report Nozzle Storage Program," Report No. TWR-546 (TW-548-2-64), Thiokol Chemical Corp., Brigham City, Utah, February 1964.

A.4.5.14 "Stage I MINUTEMAN Ordnance Storage Program, 1963 Annual Report," Report No. TWR-536, Thiokol Chemical Corp., Brigham City, Utah, 13 January 1964.

A.4.5.15 "Revision I, Demonstrated and Predicted Storage Life for Full-Scale, Flight-Weight Stage I MINUTEMAN Rocket Motors," Report No. TWR-349-1, TW-537-11-63, Thiokol Chemical Corp., Brigham City, Utah, 25 November 1963.

A.4.5.16 "Demonstrated and Predicted Storage Life for Full-Scale, Flight-Weight Stage I MINUTEMAN Rocket Motors," Report No. TWR-349, TW-293-7-63, Thiokol Chemical Corp., Brigham City, Utah, 9 July 1963.

A.4.5.17 "Stage I MINUTEMAN Ordnance Storage Program, 1962 Annual Report," Report No. TWR-291, Thiokol Chemical Corp., Brigham City, Utah, 1 July 1963.

A.4.5.18 "Long-Term Storage and Accerated Aging Summary Report, vol. II, Insulation, Liner, Sealants and Miscellaneous Specimens," Report No. 666-4963, Thiokol Chemical Corp., Brigham City, Utah, 22 June 1961.

Stage II

A.4.5.19 "Ten-Year Aging and Storage Program, Wing VI MINUTEMAN Second Stage Motors and Components Program Progress," Report No. 0162-06QAS-3, Aerojet-General Corp., Sacramento, California, 20 January 1966.

A.4.5.20 "Ten-Year Aging and Storage Program, Wings I through V, MINUTEMAN Second Stage Motors and Components," Report No. 0162-01-QAS-8, Aerojet-General Corp., Sacramento, California, 20 January 1966.

A.4.5 PROGRESS REPORTS ON MINUTEMAN AGING PROGRAM (Continued)

Stage II (Continued)

A.4.5.21 "Weapon System 133B, Ten-Year Aging and Storage Program, Wing VI, MINUTEMAN Second Stage Motors and Components," Report No. 0162-06QAS-2, Aerojet-General Corp., Sacramento, California, 20 October 1965.

A.4.5.22 "Ten-Year Aging and Storage Program, Wings I through V, MINUTEMAN Second Stage Motors and Components," Report No. 0162-01QAS-7, Aerojet-General Corp., Sacramento, California, 20 October 1965.

A.4.5.23 "Ten-Year Aging and Storage Program, Wing VI MINUTEMAN Second Stage Motors and Components," Report No. 0162-06WAS-2, Aerojet-General Corp., Sacramento, California, 20 October 1965.

A.4.5.24 "Ten-Year Aging and Storage Program, Wings I through V, MINUTEMAN Second Stage Motors and Components," Report No. 0162-01QAS-6, Aerojet-General Corp., Sacramento, California, 20 July 1965.

A.4.5.25 "Ten-Year Aging and Storage Program, Wing VI MINUTEMAN Second Stage Motors and Components," Report No. 0162-06WAS-1, Aerojet-General Corp., Sacramento, California, 30 May 1965.

A.4.5.26 "Weapon System 133B, Ten-Year Aging and Storage Program, Wing VI, MINUTEMAN Second Stage Motors and Components," Report No. 0162-06QAS-1, Aerojet-General Corp., Sacramento, California, 30 May 1965.

A.4.5.27 "Ten-Year Aging and Storage Program, Wings I through V, MINUTEMAN Second Stage Motors and Components," Report No. 0162-01QAS-5, Aerojet-General Corp., Sacramento, California, 20 April 1965.

A.4.5.28 "Development of a Solid Propellant Rocket Motor, Second Stage, Wing VI MINUTEMAN Missile," Report No. 0162-026A-7, Aerojet-General Corp., Sacramento, California, 2 March 1965.

A.4.5.29 "Aging and Storage Program, Wings I through V, MINUTEMAN Second Stage Motors and Components," Report No. 0162-01WAS-4, Aerojet-General Corp., Sacramento, California, January 1965.

A.4.5.30 "Development of a Solid Propellant Rocket Motor, Second Stage, Wing VI MINUTEMAN Missile," Report No. 0162-026Q-6, Aerojet-General Corp., Sacramento, California, 30 November 1964.

A.4.5 PROGRESS REPORTS ON MINUTEMAN AGING PROGRAM (Continued)

Stage II (Continued)

A.4.5.31 "Aging and Storage Program, Wings I through V, MINUTEMAN Second Stage Motors and Components," Report No. 0162-01 QAS-3, Aerojet-General Corp., Sacramento, California, October 1964.

A.4.5.32 "Development of a Solid Propellant Rocket Motor, Second Stage, Wing VI MINUTEMAN Missile," Report No. 0162-026Q-5, Aerojet-General Corp., Sacramento, California, 30 August 1964.

A.4.5.33 "Aging and Storage Program, Wings I through V, MINUTEMAN Second Stage Motors and Components," Report No. 0162-01QAS-2, Aerojet-General Corp., Sacramento, California, 20 July 1964.

A.4.5.34 "Development of a Solid Propellant Rocket Motor, Second Stage, Wing VI MINUTEMAN Missile," Report No. 0162-026Q-4, Aerojet-General Corp., Sacramento, California, 30 May 1964.

A.4.5.35 "Aging Characteristics of MINUTEMAN Polyurethane Binders," Report No. AFBSD TDR64-52, Aerojet-General Corp., Sacramento, California, May 1964.

A.4.5.36 "Weapon System 133A, Aging and Storage Program, Wings I through V MINUTEMAN Second Stage Motors and Components," Report No. 0162-01QAS-1, Aerojet-General Corp., Sacramento, California, 20 April 1964.

A.4.5.37 "Development of a Solid Propellant Rocket Motor, Second Stage, Wing VI MINUTEMAN Missile," Report No. 0162-026Q-3, Aerojet-General Corp., Sacramento, California 1 March 1964.

A.4.5.38 "Development of a Solid Propellant Rocket Motor, Second Stage, Wing VI MINUTEMAN Missile," Report No. 0162-026Q-2, Aerojet-General Corp., Sacramento, California, 30 November 1963.

A.4.5.39 "Development of a Solid Propellant Rocket Motor, Second Stage, Wing VI MINUTEMAN Missile," Report No. 0162-026Q-1, Aerojet-General Corp., Sacramento, California, 30 August 1963.

Stage III

A.4.5.40 "Surveillance Quarterly Report, MINUTEMAN Stage III, Weapon System 133A LGM-30," Report No. MTO-521-3, Hercules Powder Co., Magna, Utah, 20 January 1966.

A.4.5 PROGRESS REPORTS ON MINUTEMAN AGING PROGRAM (Continued)

Stage III (Continued)

A.4.5.41 "Surveillance Quarterly Report," Report No. MTO-521-3, Hercules Powder Co., Magna, Utah, 20 January 1966.

A.4.5.42 "Surveillance Quarterly Report," Report No. MTO-521-2, Hercules Powder Co., Magna, Utah, 20 October 1965.

A.4.5.43 "Surveillance Quarterly Report," Report No. MTO-521-1, Hercules Powder Co., Magna, Utah, 20 July 1965.

A.4.5.44 "Surveillance Quarterly Report," Report No. MTO-201-9, Hercules Powder Co., Magna, Utah, 20 April 1965.

A.4.5.45 "Surveillance Quarterly Report," Report No. MTO-201-8, Hercules Powder Co., Magna, Utah, 20 January 1965.

A.4.5.46 "Surveillance Quarterly Report," Report No. MTO-201-7, Hercules Powder Co., Magna, Utah, 20 October 1964.

A.4.5.47 "Surveillance Quarterly Report," Report No. MTO-201-6, Hercules Powder Co., Magna, Utah, 20 July 1964.

A.4.5.48 "Surveillance Quarterly Report," Report No. MTO-201-5, Hercules Powder Co., Magna, Utah, 20 April 1964.

A.4.5.49 "Surveillance Quarterly Report," Report No. MTO-201-4, Hercules Powder Co., Magna, Utah, 8 February 1964.

A.4.5.50 "Surveillance Quarterly Report," Report No. MTO-201-3, Hercules Powder Co., Magna, Utah, 20 October 1963.

A.4.5.51 "Surveillance Quarterly Report," Report No. MTO-201-2, Hercules Powder Co., Magna, Utah, 31 July 1963.

A.4.5.42 "Surveillance Quarterly Report," Report No. MTO-201-1, Hercules Powder Co., Magna, Utah, 7 May 1963.

A.4.5.53 "Surveillance Quarterly Report," Hercules Powder Co., Magna, Utah, October-December 1962.

A.4.5.54 "Surveillance Quarterly Report," July-September 1962, Report No. MTO-269-13, Hercules Powder Co., Magna, Utah, 11 October 1962.

A.4.5.55 "Surveillance Quarterly Report," Hercules Powder Co., Magna, Utah, April-June 1962.

A.4.5.56 "Surveillance Quarterly Report," Hercules Powder Co., Magna, Utah, January-March 1962.

A.4.5 PROGRESS REPORTS ON MINUTEMAN AGING PROGRAM (Continued)

Stage III (Continued)

Retro and Tumble Motors

A.4.5.57 "Data Package, Retro and Tumble Motor Aging Program," Security No. 08765d, Hercules Powder Co., Kenvil, New Jersey, 20 May 1965.

A.4.5.58 "Aging Program, Retro and Tumble Rocket Motors, Wing II MINUTEMAN Reverse Thrust System," Report No. K-35/MR-704-9, Hercules Powder Co., Kenvil, New Jersey, 30 September 1964.

A.4.5.59 "Aging Program, Retro and Tumble Rocket Motors, Wing II, MINUTEMAN Reverse Thrust System," Report No. K-35/MR-704-8, Hercules Powder Co., Kenvil, New Jersey, 10 February 1964.

A.4.5.60 "Aging Program, Retro and Tumble Rocket Motors, Wing II, MINUTEMAN Reverse Thrust System," Report No. K-35/MR-704-7, Hercules Powder Co., Kenvil, New Jersey, 6 January 1964.

Propulsion Subsystems, General

A.4.5.61 "Motor Storage Surveillance Program Quarterly Report," Report No. 4459-0104-T0000, TRW Systems, 31 December 1965.

A.4.5.62 "Motor Storage Surveillance Program Quarterly Report," Report No. 4459-0100-TU000, TRW Systems, 3 September 1965.

A.4.5.63 "MINUTEMAN Motor Storage Surveillance Program Quarterly Progress Report," Report No. 6440-0100-TU000, Space Technology Laboratory, 30 June 1965.

A.4.5.64 "Propulsion System Evaluation Wing I MINUTEMAN FTM 537, Stages I and II," Report No. 6440-6007-TC000, Space Technology Laboratory, 30 June 1965. (C)

Stage I motor 34 months old in this flight test; results satisfactory.

A.4.5.65 "MINUTEMAN Motor Storage Surveillance Program, Quarterly Program Report," Report No. 6650.03.65-021K, Space Technology Laboratory, 30 January 1965. (C)

A. 4. 5 PROGRESS REPORTS ON MINUTEMAN AGING PROGRAM (Continued)

Stage III (Continued)

A. 4. 5. 66 "MINUTEMAN Motor Storage Surveillance Program, Quarterly Progress Report," Report No. 6650.03-64-127K, Space Technology Laboratory, 31 October 1964.

A. 4. 5. 67 "MINUTEMAN Motor Storage Surveillance Program Quarterly Progress Report," Report No. 6650.03-64-081K Space Technology Laboratory, 31 July 1964.

A. 4. 5. 68 "MINUTEMAN Motor Storage Surveillance Program, Quarterly Progress Report," Report . 6123 Z167-TC000, Space Technology Laboratory, 30 April 1964.

A.4.6 FULL-SCALE MOTOR REPORTS

Stage I

A.4.6.1 "STM 028, Final Storage and Static Test Reports, Full-Scale, Stage I, MINUTEMAN Surveillance Test Motor," Report No. TWR-1539, Thiokol Chemical Corp., Brigham City, Utah, November 1965.

A.4.6.2 "STM 006, Final Storage and Static Test Report, Stage I MINUTEMAN Storage Test Motor," Report No. TWR-1685, TC 1-249-1-6, Thiokol Chemical Corp., Brigham City, Utah, August 1965.

A.4.6.3 "STM 010, Storage and Static Test Report, Stage I MINUTEMAN Storage Test Motor," Report No. TWR-904 (TW-318-2-65), Thiokol Chemical Corp., Brigham City, Utah, February 1965.

A.4.6.4 "STM 023, TU-122-1818.1009, Final Storage and Static Test Report, Full-Scale Stage I MINUTEMAN Storage Test Motor," Report No. TWR-770, Thiokol Chemical Corp., Brigham City, Utah, October 1964.

A.4.6.5 "STM 004, Final Storage and Static Test Report, Full-Scale, Flight-Weight, Stage I MINUTEMAN Storage Test Motor 004 TU-122-1518.57," Report No. TWR-550 (TW-516-1-64), Thiokol Chemical Corp., Brigham City, Utah, January 1964.

A.4.6.6 "STM 019, Final Static Test Results TU-122-1518.65, Full-Scale, Stage I, Flight-Weight MINUTEMAN Storage Test Motor," Report No. TW-532-9-63, Thiokol Chemical Corp., Brigham City, Utah, September 1963.

A.4.6.7 "STM 019, Final Storage Report, Full-Scale, Stage I, Flight-Weight MINUTEMAN Storage Test Motor TU-122-1518.65," Report No. TW-677-9-63, Thiokol Chemical Corp., Brigham City, Utah, September 1963.

A.4.6.8 "STM 016, Final Storage Report, Full-Scale, Flight-Weight, Stage I MINUTEMAN Storage Test Motor TU-122-1518.201," Report No. TW-679-8-63, Thiokol Chemical Corp., Brigham City, Utah, August 1963.

A.4.6.9* "STM 016, Final Static Test Results, TU-122-1518.201, Full-Scale, Stage I, Flight-Weight MINUTEMAN Storage Test Motor," Report No. TW-624-8-63, Thiokol Chemical Corp., Brigham City, Utah, August 1963.

*This reference inadvertantly duplicated, see A.4.6.8.

A. 4. 6 FULL-SCALE MOTOR REPORTS (Continued)

Stage I (Continued)

A. 4. 6. 10 "STM 003, Final Storage Report, Full-Scale, Flight-Weight, Stage I, MINUTEMAN Storage Test Motor TU-122-1518. 106," Report No. TWR-258 (TW-696-6-63), Thiokol Chemical Corp., Brigham City, Utah, June 1963.

A. 4. 6. 11 "STM 003, Final Static Test Results TU-122-1518. 106, Full-Scale, Stage I, Flight-Weight MINUTEMAN Storage Test Motor," Report No. TWR-277 (TW-693-4-63), Thiokol Chemical Corp., Brigham City, Utah, April 1963.

A. 4. 6. 12 "Summary and Analysis of Storage Data for Full-Scale, Flight-Weight Stage I MINUTEMAN Rocket Motors," Report No. TWR-54, TW-709-1-63, Thiokol Chemical Corp., Brigham City, Utah, 27 March 1963.

A. 4. 6. 13 "Summary and Analysis of Storage Data for Full-Scale, Flight-Weight Stage I MINUTEMAN Motor," Report No. TW 709-1-63, Thiokol Chemical Corp., Brigham City, Utah, 25 March 1963.

A. 4. 6. 14 "STM 011, Static Test Results, TU-122-1518. 83 Full-Scale, Stage I, Flight-Weight, MINUTEMAN Storage Motor," Report No. IT-3705 (TW-192-11-62), Thiokol Chemical Corp., Brigham City, Utah, November 1962.

A. 4. 6. 15 "Final Test Results, TU-122-153-73, Full-Scale Stage I, Flight-Weight MINUTEMAN Development Motor," Report No. TTM-003, TW-1-10-62, IT3550, Thiokol Chemical Corp., Brigham City, Utah, September 1962.

A. 4. 6. 16 "STM 001, Final Report, Full-Scale, Flight-Weight, Stage I, MINUTEMAN Storage Test Motor TU-122-1518. 54," Report No. IT-3341 (TW-184-8-62), Thiokol Chemical Corp., Brigham City, Utah, August 1962.

A. 4. 6. 17 "STM 001, Final Test Results, TU-122-1518. 54 Full-Scale, Stage I, Flight-Weight, MINUTEMAN Storage Motor," Report No. IT-3318 (TW-56a-7-62), Thiokol Chemical Corp., Brigham City, Utah, July 1962.

A. 4. 6. 18 "STM 020, Final Storage Test Results, MINUTEMAN Engine TU-122-1518. 42," Report No. IT-2608, Thiokol Chemical Corp., Brigham City, Utah, 28 November 1961.

A. 4. 6 FULL-SCALE MOTOR REPORTS (Continued)

Stage II

A. 4. 6. 19 "Static Test Firing of Second Stage Wing VI MINUTEMAN Motor 52MS-EX-3, Final Report," Report No. 0162-02TR-52MS-EX-3, Aerojet-General Corp., Sacramento, California, 15 November 1965.

A. 4. 6. 20 "Weapon System 133A, Final Report, Static Test Firing of Second Stage MINUTEMAN Motor 44ES-7," Report No. 0162-01TR-ES-7, Aerojet-General Corp., Sacramento, California, 11 May 1965.

A. 4. 6. 21 "Weapon System 133A, Final Report, Static Test Firing of Second Stage MINUTEMAN Motor 44ES-21," Report No. 0162-01TR-ES-21, Aerojet-General Corp., Sacramento, California, 30 March 1965.

A. 4. 6. 22 "Weapon System 133A, Final Report, Static Test Firing of Second Stage MINUTEMAN Motor 44ES-1, Report No. 0162-01TR-ES-1, Aerojet-General Corp., Sacramento, California, 30 July 1964.

A. 4. 6. 23 "Static Test Firing of Second Stage MINUTEMAN Motor 44A-1," Report No. 0162-01TR-A-1, Aerojet-General Corp., Sacramento, California, 26 April 1964.

A. 4. 6. 24 "Weapon System 133A, Final Report, Static Test Firing of Second Stage MINUTEMAN Motor 44ES-6," Report No. 0162-01TR-ES-6, Aerojet-General Corp., Sacramento, California, 13 October 1963.

A. 4. 6. 25 "Weapon System 133A, Final Report, Static Test Firing of Second Stage MINUTEMAN Motor 44SX-7," Report No. 0162-01TR-SX-7, Aerojet-General Corp., Sacramento, California, July 1963.

A. 4. 6. 26 "Static Test Firing of Second Stage MINUTEMAN Motor 44A-4," Report No. 0162-01TR-A-4, Aerojet-General Corp., Sacramento, California, 10 May 1963.

PFRT, Wing I, 26 mos. old. Failed after 8 seconds; separation between inner and outer grains at forward end, aft of forward skirt. Unaged igniter.

A. 4. 6. 27 "Weapon System 133A, Static Test Firing of Second Stage MINUTEMAN Motor 44SX-9," Report No. 0162-01TR-SX-9, Aerojet-General Corp., Sacramento, California, 28 January 1963.

A. 4. 6 FULL-SCALE MOTOR REPORTS (Continued)

Stage II (Continued)

A. 4. 6. 28 "Static Test Firing of Second Stage MINUTEMAN Motor 44A-6," Report No. 0162-01TR-A-6, Aerojet-General Corp., Sacramento, California, 27 September 1962.

A. 4. 6. 29 "Static Test Firing of Second Stage MINUTEMAN Motor 44A-3," Aerojet-General Corp., Sacramento, California, 3 November 1961.

Stage III

A. 4. 6. 30 "Final Report, Motor SD 22," Report No. MTO-164-248, Hercules Powder Co , Magna, Utah, 19 August 1965.

A. 4. 6. 31 "Final Report, Surveillance Motor Firing No. 127A, 2-5-1," Report No. MPO-164-241, Hercules Powder Co., Magna, Utah, 21 July 1965.

A. 4. 6. 32 "Final Report, Wing I, Surveillance Motor Firing No. 243B, 1-5-2," Report No. MTO-164-230, Hercules Powder Co., Magna, Utah, 6 April 1965.

A. 4. 6. 33 "Final Report, Surveillance Motor Firing No. 243B, 1-5-7," Report No. MTO-164-210, Hercules Powder Co., Magna, Utah, 14 October 1964.

A. 4. 6. 34 "Final Report, Wing I, Surveillance Motor Firing No. 243B, 1-5-6," Report No. MTO-164-161, Hercules Powder Co., Magna, Utah, 26 November 1963.

A. 4. 6. 35 "Final Report, Wing I, Surveillance Motor Firing No. 243B, 1-5-5," Report No. MTO-164-98, Hercules Powder Co., Magna, Utah, 2 July 1963.

A. 4. 6. 36 "Final Report, Surveillance Motor Firing No. 243B, 1-5-10," Report No. MTO-164-126, Hercules Powder Co., Magna, Utah, 4 June 1963.

A. 4. 6. 37 "Final Report, Wing I, Continued Development Firing No. 243B, 1-5-3," Report No. MTO-164-114, Hercules Powder Co., Magna, Utah, 27 December 1962.

A. 4. 6. 38 "Final Report, Wing I Surveillance Motor Firing No. 243B, 1-5-4," Report No. MTO-164-66, Hercules Powder Co., Magna, Utah, October 1962.

A. 4. 6. 39 "Final Report, Wing I Surveillance Motor, Firing No. 243B, 1-5-13," Report No. MTO-164-50, Hercules Powder Co., Magna, Utah, 4 June 1962.

A. 4. 6 FULL-SCALE MOTOR REPORTS (Continued)

Stage III (Continued)

A. 4. 6. 40 "Final Report, Firing No. MT . 03," Report No. MTO-164-45, Hercules Powder Co., Magna, Utah, 30 January 1962.

Retro and Tumble Motors

A. 4. 6. 41 "Surveillance and Storage Program Motor Data, Tumble," Motor data from 5 lots of propellant, Hercules Powder Co., Kenvil, New Jersey, 4 December 1965.

A. 4. 6. 42 "Aging Program Flight and Acceleration Vibration Tests, Retro/Tumble Motors," Report No. K50-51/RTC-339, Hercules Powder Co., Kenvil, New Jersey, 18 December 1963.

A. 4. 6. 43 "Surveillance and Storage Program Motor Data, Retro," Motor data on motors from 3 lots of propellant, Hercules Powder Co., Kenvil, New Jersey, 4 December 1963.

A. 4. 6. 44 "Surveillance and Storage Program Motor Data (Retro)," Report No. K-35/MC-1276, Hercules Powder Co., Kenvil, New Jersey, 4 December 1963.

A. 4. 7 OPERATIONAL STORAGE PROGRAM REPORTS

Stage I

A. 4. 7. 1 "Zero-Time LGM-30 First Stage (Aft Closure) Wings II-V Test Results," 18 March 1965.

A. 4. 7. 2 "Zero-Time LGM-30 First Stage Wings II-V Test Results," 17 March 1965.

A. 4. 7. 3 "Zero-Time LGM-30A First Stage (Aft Closure) Test Results," Supplement 1, 24 June 1964.

A. 4. 7. 4 "Supplemental Test Results from Low Modulus LGM-30B First Stage Propellant," 12 June 1964.

A. 4. 7. 5 "Zero-Time LGM-30A First Stage (Aft Closure) Test Results," 9 June 1964.

A. 4. 7. 6 "Test Results from Low Modulus LGM-30B First Stage Propellant," 18 May 1964.

A. 4. 7. 7 "Tensile Data from Thiokol Propellant Which Cracked in the Motor," 17 April 1964.

A. 4. 7. 8 "Zero-Time LGM-30A First Stage Test Results," Supplement 1, 30 March 1964.

A. 4. 7. 9 "LGM-30A First Stage Test Data (Missile in Silo)," Supplemental Report, February 1964.

A. 4. 7. 10 "Zero-Time LGM-30A First Stage Test Results," 29 January 1964.

Stage II

A. 4. 7. 11 "Zero-Time Wings II-V LGM-30 Second Stage (Inner) Test Results," 15 January 1965.

A. 4. 7. 12 "Zero-Time Wings II-V LGM-30 Second Stage (Outer) Test Results," 23 October 1964.

A. 4. 7. 13 "Zero-Time LGM-30A Second Stage (Middle Outer) Test Results," 27 March 1964.

A. 4. 7. 14 "Zero-Time LGM-30A Second Stage (Middle Inner) Test Results," Supplement 1, 25 March 1964.

A. 4. 7. 15 "Zero-Time LGM-30A Second Stage (Middle Inner) Test Results," 10 February 1964.

A. 4. 7 OPERATIONAL STORAGE PROGRAM REPORTS (Continued)

Stage III

A. 4. 7. 16 "Test Results for MINUTEMAN LGM-30, Stage 3," Report No. OOMQQCC NR 48(66), OOAMA, Hill Air Force Base, Ogden, Utah, 11 March 1966.

A. 4. 7. 17 "Final Report, MINUTEMAN Stage III, Ogden Air Material Area Material Support Effort," Report No. MTO-752-46, Hercules Powder Co., Magna, Utah, 15 August 1965.

A. 4. 7. 18 "Progress Report, MINUTEMAN Stage III, Ogden Air Material Area Support Effort," Report No. MTO-752-45, Hercules Powder Co., Magna, Utah, 25 June 1965.

A. 4. 7. 19 "Revised Zero-Time LGM-30A Third Stage Test Results," 14 May 1964.

Propulsion Subsystems, General

A. 4. 7. 20 "LGM30A Recycle Report," Ogden Air Material Area, undated.

Abstract contains a compilation of all MINUTEMAN recycle reports on LGM 30A weapon systems returned from Air Force between January 1963 and January 1965. (C)

A. 4. 7. 21 "CTL LGM-30A Test Results," August and September 1964.

A. 4. 7. 22 "CTL LGM-30A Test Results," May and June 1964.

A. 4. 7. 23 "CTL LGM-30A Test Results," April 1964.

A. 4. 7. 24 "LGM-30 Aging and Surveillance Testing Program Progress Report," 10 December 1963.

A. 5 MISCELLANEOUS

Stage I

A. 5. 1 "Technical Manual, Overhaul with Group Assembly Parts List, Rocket Motor, Wing I (M55) and Wing II (M55A1)," Report No. TO 2K-SRM55-3, USAF, 1 September 1963.

Stage II

A. 5. 2 "Technical Manual, Overhaul with Illustrated Parts Breakdown, Rocket Motor SR19-AJ-1, USAF LGM 30F, T.O. 2K-SR19-3," Aerojet-General Corp., Sacramento, California, (changed 15 October 1965), 25 July 1965.

Stage III

A. 5. 3 "Technical Manual, MINUTEMAN Third Stage Rocket Motor, M57 and M57A1, Overhaul Instructions with Group Assembly Parts List," Hercules Powder Co., Magna, Utah, 15 July 1965.

Retrofit document.

Propulsion Subsystems, General

A. 5. 4 "Logistic Temperature Environments of the MK 56, Mod 1 Warhead," SCDR 226-62, Sandia Corp., Albuquerque, New Mexico, June 1963.

(The contents of this report are Secret.)

III-B GENERAL SURVEILLANCE AND AGING INFORMATION

Much of the information on aging and surveillance up to 1961 is included in the minutes of the JANAF Solid Propellant Surveillance Panel meetings, References B.1 through B.8. The proceedings of the JANAF panel on Physical Properties of Solid Propellants, References B.9 through B.16 also contain some papers on surveillance test methods. References B.17 through B.24 are of interest because the proceedings of the ICRPG Working Group on Mechanical Behavior of Solid Propellants now contain the papers on surveillance subsequent to 1961.

In addition to the above references, B.25 through B.29 describe various nondestructive test methods that have been developed as tools for monitoring aging effects.

This subsection is presented independently because the above references are too diverse to be included in any of the other subsections of this report.

B.1 "Bulletin of the Sixth Meeting of the JANAF-ARPA-NASA Solid Propellant Surveillance Panel," SPIA, Publication No. SPSP/9, 5-7 December 1961. (C)

In addition to papers dealing with propellant aging, the following papers are presented:

"Critical Problem Areas in Surveillance," W.L. Rollwitz

"Minuteman Surveillance," B. Dubrow

B.2 "Addendum of the Sixth Meeting of the JANAF-ARPA-NASA Solid Propellant Surveillance Panel," Published by SPIA, 5-7 December 1961.

Aside from propellant aging, papers presented include:

"Air Force Surveillance Problems"

"Solid Propellant Surveillance Techniques," O.P. Bruno

"Type-Life Program — An Engineering Surveillance Tool"

"Report of East Coast Committee on Acceptable Surveillance Test Methods"

"Report of Southern Acceptable Methods Committee of JANAF-ARPA-NASA Solid Propellant Surveillance Panel"

"Preliminary Study of Acceptable Methods for Solid Propellant Rocket Motor Surveillance"

"Current Status of Failure Criteria Studies"

B.3 "Bulletin of the Joint Meeting JANAF Panels on Physical Properties (19th Meeting) and Surveillance (5th Meeting) of Solid Propellants," Publication No. PP-13/SPSP-8, Solid Propellant Information Agency, Applied Physics Laboratory, Johns Hopkins University, Silver Springs, Maryland, 20-22 September 1960. (C)

Papers presented include:

"Comparative Effects of Chemical Deterioration and Physical Change Within Solid Propellants"

"Ten Years of Polysulfide Propellant Aging"

"Effects of Humidity on the Mechanical Properties of Selected Polysulfide and Polyurethane Propellants"

"Selection of Tests for Following the Aging Effects of Polyurethane Propellants Containing Aluminum"

"Laboratory Techniques for Determination of Thermal Stability"

"Aging Characteristics of Certain Carboxylated Butadine-Acrylonitrile Propellants"

"Use of Surveillance Data in Support of a Development-Stage Decision"

"Environmental Testing of Ordnance Items in Desert and Arctic"

B.4 "Bulletin of the Fourth Meeting, JANAF Solid Propellant Surveillance Panel," Salt Lake City, Utah, 10-11 December 1959, SPIA, Publication No. SPSP/7, November 1959.

"Fourteen Papers on Aging and Stability of Solid Propellant Systems"

B.5 "Addendum to Bulletin of the Third Meeting of the JANAF Solid Propellant Surveillance Panel," Aerojet-General Corp., Sacramento, California. SPIA, Publication No. SPSP/6, 109 pp., September 1959 (C)

"Sensitivity of Propellants: The Adiabatic Self-Healing of AHA, Arcite 358, and ANP-2639 AF"

"Accelerated Aging of Polyurethane Propellants"

"Air Force Aging Studies and Field Surveillance Procedures"

"Surveillance Test Methods"

"Sealing Techniques and Chemical Test Methods"

"Laboratory Ballistics Tests"

"Physical Properties Tests"

"Nondestructive Testing"

"Statistical Methods"

B.6 "Bulletin of the Third Meeting, JANAF Solid Propellant Surveillance Panel," SPIA, Publication No. SPSP/5, pp 99, October 1958. (C)

"Propellant Behavior at Low Temperatures"

"Storage Stability of Some Ammonium Perchlorate/Polyurethane Propellants"

"Surveillance of Torpedo Booster Motor, MK1/Mod 0 of Rocket Thrown Torpedo"

"Nondestructive Techniques for Propellant Evaluation, Part II: Prediction of Aging Characteristics"

"A Comparison of the Surveillance Characteristics of the Sergeant Motor with Laboratory and Scale Motor Tests"

B.7 "Addendum to Bulletin of the Second Meeting of the JANAF Solid Propellant Surveillance Panel," 77 pp., numerous tables and figures, SPIA, Publication No. SPSP/4, November 1957. (C)

"Stability of Rubber-Base Ammonium/Nitrate Propellants; Aging Characteristics of the Polyurethane Propellants Developed for the Hawk Engine"

B.8 "Bulletin of the Second Meeting of the JANAF Solid Propellant Surveillance Panel," 171 pp., numerous tables and figures, SPIA, Publication No. SPSP/3, November 1957. (C)

"Surveillance Experience with Thiokol Polysulfide Solid Propellant Engines"

"Creep Failure in the Sergeant Motor"

"Surveillance Experience During the Development of the M35 (T205) Rocket Motor"

"Effect of Elevated and Magazine Temperature Storage on Solid Rocket Propellants and Rocket Motors"

"Nitrocellulose Stability"

B.9 "Bulletin of the 20th Meeting, JANAF Panel on Physical Properties of Solid Propellants," vol. 2, AD-326945, 14-16 November 1961.

B.10 "Bulletin of the 17th Meeting of the JANAF Panel on Physical Properties of Solid Propellants," SPIA, Publication No. PP-11, 233 pp., May 1958. (C)

"Evaluation of Brown University Stress Analysis Work"

"A Survey of Solid Propellant Stress Analysis Procedures"

"Experience with the Alinco High Rate Tensile Tester"

"The Alinco High Rate Tester"

"The Effect of Strain Rate on Mechanical Properties of Solid Propellants of the Double-Base Type"

"Apparatus for the Measurement of Stress Relaxation Behavior"

Review Work at Member Facilities:

Aerojet-General Corp.

Allegany Ballistics Laboratory

Canadian Armament Research and Development Establishment

Jet Propulsion Laboratory

Phillips Petroleum Co.

Rohm and Haas Co.

Thiokol Chemical Corp.

Naval Ordnance Test Station

U. S. Naval Power Factory

B.11 "Bulletin of 16th Meeting of JANAF Panel on Physical Properties of Solid Propellants," SPIA/PP10, May 1957.

B.12 "Bulletin of 15th Meeting of JANAF Panel on Physical Properties of Solid Propellants," SPIA/PP9, May 1956.

B.13 "Proceedings of the 14th Meeting of JANAF Panel on Physical Properties of Solid Propellants," SPIA/PP7, December 1955.

B.14 "Proceedings of the 10th Meeting of JANAF Panel on Physical Properties of Solid Propellants," SPIA/PP3, December 1954.

B.15 "Mechanical Properties of Solid Propellants," SPIA/PP2, July 1953.

B.16 "Mechanical Properties of Solid Propellants," SPIA/PP1, June 1952.

B.17 "Bulletin of the Fourth Meeting of the ICRPG Working Group on Mechanical Behavior," vol. I, CPIA Publication No. 94a, October 1965.

B.18 "Bulletin of the Fourth Meeting of the ICRPG Working Group on Mechanical Behavior," vol. II, CPIA Publication No. 94c, October 1965.

B.19 "Report of the ad hoc Committee on Surveillance (Addendum), Bulletin of the Third Meeting of the ICRPG Working Group on Mechanical Behavior," vol. III, CPIA Publication No. 61A, pp. 33-34, April 1965.

B.20 "Bulletin of the Third Meeting of the ICRPG Working Group on Mechanical Behavior," vol. I, CPIA Publication No. 61a, October 1964.

B.21 "Bulletin of the Third Meeting of the ICRPG Working Group on Mechanical Behavior," vol. II, CPIA Publication No. 61c, October 1964.

B.22 "Report of the ICRPG Working Group on Mechanical Behavior," ad hoc Committee on Surveillance, 19 November 1963.

B.23 "Report of the ad hoc Committee on Surveillance, Bulletin of the Second Meeting of the ICRPG Working Group on Mechanical Behavior," CPIA Publication No. 27, October 1963.

B.24 "Addendum to the Bulletin of the Second Meeting of the ICRPG Working Group on Mechanical Behavior," CPIA Publication No. 27A, February 1964.

B.25 J. Cole, "Nondestructive Testing of Large Rocket Motors—A State of the Art Survey," Bulletin of Joint Meeting JANAF Panels on Physical Properties and Surveillance of Solid Propellants, September 1960.

B.26 R. Amrein, and M. Bassen, "Various Techniques for Determining the Effects of Aging Upon Solid Propellants," Bulletin of Fourth Meeting of JANAF Solid Propellant Surveillance Panel, December 1959.

B.27 "Addendum to Symposia on Scale and Nondestructive Testing, JANAF Solid Propellant Static Test and Surveillande Panels," SPIA, Publication No. SPS-NDT/1A, 94 pp., October 1958. (C)

"Determination of Ballistic Parameters of Uncured Composite Propellants by Closed Bomb and Strand Burner Methods"

"Correlation of Small Scale and Full Scale Rocket Motor Burning Rates"

"Prediction of Ballistic Performance of Solid Propellant Rockets from Strand and Small Scale Motor Tests"

"Nondestructive Testing of Solid Propellant Motors"

B.28 Symposia on Scale and Nondestructive Testing, JANAF Solid Propellant Rocket Static Test and Surveillance Panels," SPIA, Publication No. SPS-NDT/1, 119 pp., October 1958. (C)

"Scale Testing of BDI A Cast Double-Base Formulation"

"Small Scale Testing"

"An Analysis of 5-inch Test Motor Firing in the T50 and T52E3 JATO Programs"

"The Prediction of Static Firing Results of JATO's M5 (Nike AJAX Boosters) from Small Scale Test Data"

"Comparisons of Ballistic Properties of Scale Model and Full Size Sergeant Motors"

"Internal Inspection of Large Solid Propellant Propulsion Units by Radiological Methods"

"Nondestructive Techniques for Propellant Evaluation, Part I: General Description and Application"

B.29 "Addendum to Seventh Meeting Bulletin, JANAF Solid Propellant Rocket Static Test Panel," SPIA, 31 pp., October 1958. (C)

"Some Instrumentation Techniques for Propellant Detonation Studies"

"Straight-Pipe Diffuser Thruststand for Measuring High Altitude Rocket Performance"

B.30 H. Briar, "A Statistical Model for Constant Strain Failures in Solid Rocket Propellants," Bulletin of the Fourth Meeting of the ICRPG Working Group on Mechanical Behavior, CPIA Publication No. 94u pp. 321-331, October 1965.

B.31 "Rocket Motor Manual," SPIA/M1, vol. II, CPIA, Applied Physics Laboratory, Johns Hopkins University, Silver Springs, Maryland, May 1965.

B.32 K. Bills, Jr., G. Svob, et al., "A Cumulative-Damage Concept for Propellant-Liner Bonds and Its Application to Solid Rocket Motors," AIAA Paper No. 65-191, presented at the AIAA Sixth Solid Propellant Rocket Conference, 1-3 February 1965.

B.33 C. Surland, "Propellant Mechanical Behavior under Superimposed Hydrostatic Pressure," Presented at the Third Meeting of the ICRPG Working Group on Mechanical Behavior, October 1964.

B.34 J. Vernon, "The Significance of Transient Thermal Strains in Case-Bonded Rocket Motors," Bulletin of the Third Meeting of the ICRPG Working Group on Mechanical Behavior, CPIA Publication No. 61U, pp. 75-90, October 1964.

B.35 K. Bills, Jr., and J. Wiegand, "The Relation of Mechanical Properties to Solid Rocket Motor Failure," ARS Preprint No. 2748-63, presented at ARS Solid Propellant Rocket Conference, 30 January - 1 February 1963.

B.36 L. Herrman and M. Tamekuni, "Horizontal Slump of an Elastically-Encased Propellant," Bulletin of the First Meeting of the ICRPG Working Group on Mechanical Behavior, CPIA Publication No. 2, pp. 6-7, December 1962.

B.37 P. Colodny, D. DeLao, et al., "Low Temperature Aging of Polyurethane Propellants," Addendum to the Bulletin of the Sixth Meeting of the JANAF-ARPA-NASA Solid Propellant Surveillance Panel, SPIA, Publication No. SPSP/6A, pp. 89-106, 15 June 1962. (C)

B.38 H. Bartel, E. Besser, et al., "Preliminary Study of Acceptable Methods for Solid Propellant Rocket Motor Surveillance," Committee of JANAF-ARPA-NASA Solid Propellant Surveillance Panel, 15 June 1962.

B.39 E. Sienicki, "Current Developments in the Estimation of Shelf-Life for Solid Propellant Rocket Motors," Addendum of Sixth Meeting of the JANAF-ARPA-NASA Solid Propellant Surveillance Panel, December 1961.

B.40 N. Fishman and L. Hiam, "Measurements of Electrical Properties as a Nondestructive Evaluation Technique," Bulletin of Sixth Meeting of JANAF-ARPA-NASA Solid Propellant Surveillance Panel, December 1961.

B.41 M. Burns, Jr. and F. Worcester, "Type-Life Program—An Engineering Surveillance Tool," Addendum of Sixth Meeting of the JANAF-ARPA-NASA Solid Propellant Surveillance Panel, December 1961.

B.42 S. Wachtell, et al., "Report of East Coast Committee on Acceptable Surveillance Test Methods," Addendum of Sixth Meeting of the JANAF-ARPA-NASA Solid Propellant Surveillance Panel December 1961.

B.43 R. Davis, et al., "Report of Southern Acceptable Methods Committee of the JANAF-ARPA-NASA Solid Propellant Surveillance Panel, Addendum of Sixth Meeting of the JANAF-ARPA-NASA Solid Propellant Surveillance Panel, December 1961.

B.44 C. Surland, et al., "The Effect of Hydrostatic Pressure on the Uniaxial Tensile Properties of Solid Propellants," Bulletin of the 20th Meeting of the JANAF-ARPA-NASA Panel on the Physical Properties of Solid Propellants, SPIA, Publication No. 14u, pp. 341-347, October 1961.

B.45 N. Fishman, "A Surveillance Viewpoint," Bulletin of the 20th Meeting of the JANAF-ARPA-NASA Panel on Physical Properties of Solid Propellants, SPIA Publication No. 14u, pp. 1-5, October 1961.

B.46 "Report of the ad hoc Committee on Solid Propellant Storage Life, Propellants and Explosives Section, Materials Division, American Ordnance Association," 15 September 1961.

B.47 "A Study of Methods of Improving the Shelf-Life of Solid Propellant Rocket Engines," Report No. E115-61, under Contract AF 33(616)-40313, Thiokol Chemical Corp., Elkton, Maryland, 1961. (C)

B.48 "Study of Methods of Improving Shelf-Life of Existing and Contemplated Solid Rocket Motors," Report No. 0217-01F, under Contract AF 33(616)-5814, Aerojet-General Corp., 22 September 1960. (C)

B.49 "Bulletin of the Joint Meeting of the JANAF Panel on Physical Properties (19th Meeting), and the JANAF Surveillance Panel (5th Meeting), SPIA, Publication No. PP-13/SPSP-8, August 1960. (C)

B.50 K. Bills, Jr., W. Hart, et al., "Use of Mechanical Properties Test Methods for Studying the Aging Behavior of Polyurethane Propellants," Bulletin of Fourth Meeting of JANAF Solid Propellant Surveillance Panel, December 1959.

B.51 T. Smith, "Use of Mechanical Property Tests for Evaluating the Storage Stability of Composite Propellants," Bulletin of Fourth Meeting of JANAF Solid Propellant Surveillance Panel, December 1959.

B.52 "Study and Improvement of Storage Capabilities of Solid Propellant Motors," Report No. E188-59, under Contract AF 33(616)-5812, Thiokol Chemical Corp., Elkton, Maryland, 1959. (C)

B.53 J. Wiegand, "Accelerated Aging of Polyurethane Propellants," Bulletin of Third Meeting Addendum JANAF Solid Propellant Surveillance Panel SPTA, Publication No. SPSP/6, October 1958.

B.54 T. Smith, "Physical Properties Tests," Addendum to the Bulletin of the Third Meeting of the JANAF Solid Propellant Surveillance Panel, SPIA, Publication No. SPSP/6, pp. 97-102, October 1958.

B.55 "JANAF Panel on Physical Properties of Solid Propellants—Method for Determining Tensile Properties of Solid Rocket Propellants," SPIA/PP8, February 1957.

B.56 "JANAF Panel on Physical Properties of Solid Propellants—Method for Determining Tensile Properties of Solid Rocket Propellants," Part 1, SPIA/PP8, March 1956.

B.57 "Proceedings of the 13th Meeting of JANAF Panel on Physical Properties of Solid Propellants," SPIA/PP6, August 1955.

B.58 "Proceedings of the 11th Meeting of JANAF Panel on Physical Properties of Solid Propellants," SPIA/PP4, March 1955.

B.59 "Proceedings of the 12th Meeting of JANAF Panel on Physical Properties of Solid Propellants," SPIA/PP5, March 1955.

B.60 R. Froelich, "Accidental Ignition of Rocket Motors by Radar Energy," AD-366333, Applied Physics Laboratory, Johns Hopkins University, 19 August 1954.

B.61 K. Bills, Jr. and W. Hart, et al., "The Use of Mechanical Properties Test Methods for Studying Aging Behavior of Polyurethane Propellants," SPIA, Publications No. SPSP/5 and SPSP/6, pp. 131-150. (C)

B.62 J. Myers, "The Role of the Analytical Chemist in Surveillance," SPTA Publications No. PP-13/SPSP-8, pp. 61-64. (C)

B.63 "Panel on Quality Control in Large Solid Propellant Rockets," R. Winter, Allegany Ballistics Laboratory, SPIA, Bulletin of the 14th Meeting, JANAF Solid Propellant Group, (Addendum), pp. 1-56. (C)

"Reliability Program for Polaris Propulsion Subsystem"

"Surveillance of Large Solid Propellant Motors"

"Acceptance Specifications for Large Solid Propellant Motors"

"Statistical Interpretation of Static and Nondestructive Test Data"

III-C. OTHER MOTOR SURVEILLANCE PROGRAMS

This section is provided as a guide to the literature references that were uncovered during the literature search relating to motor storage and surveillance programs other than MINUTEMAN. The information on some motor aging programs was extensive; however on others it was not sufficient to ascertain the scope of the program, nor the basic approach used to determine the service life or aging characteristics of the motor and components. In general it appears that major emphasis has been placed on propellant aging, which is understandable inasmuch as many of these motors, e.g. JATOS, are quite old and cartridge-loaded.

The US Naval Propellant Plant reports are probably the best single source of references on other rocket motors. These reports on Type-Life Programs (an accelerated aging scheme) and the Quality Surveillance Programs (fleet return programs) are of particular value because data are provided for a large number of solid rocket motors over a long period of time. Thus, a wealth of information on the effect of age on motor performance is referenced in Subsection C. 23, "Type Life/Surveillance Programs of Navy Rocket Motors."

References to aging and surveillance information on 23 categories of rocket motors are included in this section. These are discussed separately in the paragraphs which follow.

C.1 POLARIS

References C.1.1, C.1.2, and C.1.3 indicate that a rather comprehensive program is now being undertaken to assess the aging characteristics of POLARIS missile components after varying periods of fleet deployment. Missiles are off-loaded from the submarines, disarmed and disassembled, then returned to the vendors for nondestructive and destructive testing to ascertain the effects of age.

During development and production of the A2 and A3 models, numerous components and materials were evaluated by various accelerated aging tests. These include polyurethane liners and propellants, case bonds, insulation, O-rings, pyrotechnic materials, squibs, assembled igniters, filament-wound cases, and full-scale and sub-scale loaded motors. These are reported in References C.1.4 through C.1.38.

More information on the basic approach employed by Navy/LMSC/AGC/HPC in establishing the service life and aging behavior of the Polaris propulsion systems are in the process of being obtained. This information will be included in the bibliography of the Final Report.

C.2 ASROC

Very few specific references to the surveillance of the ASROC motor were uncovered. However, reports on motors up to 4 years old are reported, along with an evaluation of aged X2B2 igniters. The best information is given in References C.23.1 through C.23.23, which describe, among others, the Navy Type Life/surveillance Programs on ASROC.

C.3 BOAR MK 6 MOD O

References C.3.1, C.3.2, and C.3.3 describe the aging characteristics up to 5 years of the MK 6 Mod O Booster, MK 37 Mod O propellant grain and the MK 157 Mod O igniters.

C.4 BOMARC (M51)

References C.4.1 through C.4.7 describe the surveillance testing of the BOMARC booster motors (M51). Estimates of reliability of 40-month aged motors are presented in Reference C.4.2.

C.5 FALCON Series (GAR 1/2, 3/4, 8 and 11)

The demonstrated performance of motors in service for 3 years and accelerated aging conditions is reported in Subsection C.5. These 24 references also contain aging information of igniters, igniter materials, squibs, liners, propellants, propellant-liner bonds, and liner-case bonds.

C.6 2.25/2.75-INCH FOLDING FIN AIR ROCKETS (FFAR)

The aging characteristics of the FFAR rocket motors over 5 years old, reported in references in Subsection C.6 are considered important, since very large numbers of aged motors have been statically and flight tested. The volume of test data may provide a basis for a statistical analysis of the reliability degradation of these motors. In addition to evaluating the propellant grain, igniters and nozzles were examined. Some test information on aged motors fired in the "as received" condition is also provided.

during the Phase II and III efforts to categorize the components and materials in terms of their ability to withstand degradation under a variety of environmental conditions.

C.12 NIKE SERIES PROPULSION SYSTEMS

References in Subsection C.12 report on the aging characteristics of the various NIKE series propulsion systems, including NIKE HERCULES, NIKE ZEUS, NIKE AJAX and the SPRINT. These reports are of extreme value in that considerable emphasis is placed on igniter degradation and the resulting increase in ignition delay. Also, the effects of desert, tropical, and arctic environments are reported. Further, these references report on accelerated aging of other components such as propellant, liners, adhesives, sealants, and full-scale motors.

C.13 PERSHING PROPULSION SYSTEM

References in Subsection C.13 contain the aging information on the components and materials in the Pershing Propulsion System, given in status reports generated during development. Much of the information was obtained from accelerated aging tests. The effects of temperature and humidity on propellant degradation are also reviewed. Components evaluated include initiators, propellant-liner bonds, liners, and propellant. Also, the interactions between various materials and propellant are reported.

C.14 REGULUS/PRODUCER

Reports generated during the development of the REGULUS and the PRODUCER are shown in references in Subsection C.14. These reports are included because they present accelerated aging information on large ammonium nitrate propellant motors. The interactions between the case-bonded ammonium nitrate propellant and other components are reported.

C.15 SERGEANT

Reports on the shelf and service life of the SERGEANT propulsion system are given in Subsection C.15. Included is a reference on squib materials development.

C.16 SIDEWINDER Propulsion Unit and Gas Generator

Surveillance data of the SIDEWINDER Propulsion Unit and Gas Generator are reported in Subsection C.16. Data on the aging characteristics of these units may also be found under "Navy Type Life/Surveillance Programs," References C.23.1 through C.23.23.

C.17 SPARROW/SHRIKE

Since the propulsion system for the SPARROW and SHRIKE are identical except for missile interfaces, references tc these two motors are grouped together as Subsection C.17. The references cover surveillance programs conducted on the propulsion units, gas generators, S/A mechanisms, and weather seals. They also provide procedures for determining serviceability of fleet-deployed rounds.

C.18 SUBROC

References in Subsection C.18 provide aging information on the propellant and insulation materials employed in the SUBROC rocket motor. Further details on the aging and surveillance of the SUBROC may be found in "Navy Type Life/Surveillance Programs," References C.23.1 through C.23.23.

C.19 TALOS

References in Subsection C.19 describe the work that was accomplished in establishing the service life of the MK 11 Mods 1 and 2 rocket motors and the MK 177 Mod 1 igniter. It is noteworthy that the MK 11 Mod 1 was considered obsolete in 1964; however it was not determined if this obsolescence was attributed to ageout. The condition of several aged components and parts is described, including propellant, A/D switches, O-rings, and full-scale motors. Additional details on the aging characteristics of this motor may be found in "Navy Type Life/Surveillance Programs," References C.23.1 through C.23.23.

C.20 TARTAR

The aging behavior of this dual thrust rocket motor is reported in references in Subsection C.20. Three configurations are described: two composite bipropellant grains and one double base bipropellant. There is no indication of component aging. However, further aging information

on the various TARTAR configurations may also be found in "Navy Type Life/Surveillance Programs," References C. 23. 1 through C. 23. 23.

C. 21 TERRIER

References in Subsection C. 21 describe the Surveillance and Type Life tests that have been conducted with several configurations of both the booster and sustainer motors in the TERRIER. The storage characteristics of two igniters of different configuration are also described. Further details may be found in "Navy Type Life/Surveillance Programs," References C. 23. 1 through C. 23. 23.

C. 22 Miscellaneous Reports

A total of 18 references were uncovered during the literature search which pertained to the aging evaluation of a variety of other rocket motors. These miscellaneous references are included herein, with the expectation that further data will become available which will be of value in the follow-on Phase II and III effort. Among these motors are:

ALTAIR/ANTARES
ATHENA
BE3A2 ROCKET MOTOR
BULLPUP SUSTAINER
CASTOR (XM33E2)
DART (XM23)
DIMPLE MOTOR (M4)
GIMLET
QUAIL (GAM-72)
REDEYE
RETRO ROCKET (DM-18)
SCOUT (4th STAGE)
SKYBOLT
SNARK
TORPEDO MK 1 MOD O (Rat)
WOLFHOUND AND FOXHOUND/ZUNI

References in Subsection C. 22 contain information on the inspection, component testing, and firing of the above motors after various periods of storage. The components which were evaluated include propellant

grains, liners, fuzes, squibs, pyrotechnics, igniters, pressure vessels (metal and filament-wound), launchers, launch ejectors, and insulators. In addition, References C. 22. 16 and C. 22. 18 report on methods for predicting useful service life of doublebase grains based on plasticizer migration rates found under accelerated aging conditions and extrapolated to ambient conditions. Further information on some of these motors may also be found in "Navy Type Life/Surveillance Programs," References C. 23. 1 through C. 23. 23.

C. 23 Type Life/Surveillance Programs of Navy Rocket Motors

Reports issued for the Navy Type Life and Quality Surveillance Programs are listed in References C. 23. 1 through C. 23. 23. These are comprehensive reports which review the overall condition of the motor and include information on the degradation of components and materials such as igniters, insulation, propellant, bonds, inhibitors, sealants, electrical switches, leads and electrical insulations. General surveillance techniques and test methods are also described.

C.1 POLARIS

C.1.1 "Service Life Evaluation Report of Polaris A2B Missile Components, Summary Report," Report No. LMSC/804963-5, (R/C-N1-217A), Lockheed Missiles and Space Co., Sunnyvale, California, unpublished. (C)

Summarizes information and data pertaining to aging characteristics of A2B fleet-deployed hardware.

C.1.2 "Service Life Evaluation Report of Polaris A3B Missile Components, Summary Report," Report No. LMSC/805220-3 (R/C-N1-217B), Lockheed Missiles and Space Co., Sunnyvale, California, 1 April 1966. (C)

Summarizes information and data pertaining to aging characteristics of A3B fleet-deployed hardware.

C.1.3 "Service Life Evaluation Program Plan," OD-28801, Lockheed Missiles and Space Co., Sunnyvale, California, 11 December 1965.

C.1.4 "Polaris Power Plant Development," Report No. LMAC-3888-31M-10, CSTAR X64-17171, Aerojet-General Corp., Sacramento, California, June 30, 1964.

C.1.5 "Characterization and Modes of Failure of Propellant-Liner-Insulation Systems of First-and Second-Stage Polaris Model A-1 Motors," Report SRP-331, Aerojet-General Corp., Sacramento, California, 15 May 1964. (C)

Evaluates Polaris Model A-1 propellant-liner adhesive bonds. Presents data for aged and unaged samples.

C.1.6 "Polaris Power Plant Development," Report No. 3791-11Q-8, R/C-2-29, May-July 1963, Aerojet-General Corp., Sacramento, California, 31 August 1963.

Accelerated aging of A-2 liner systems.

1. At 150^{o}F propellant (ANP2639AF) and forward and aft boot liner-propellant degrades in 5 to 6 months; liner-propellant on sidewall OK after 6 months.
2. Removal of volatiles from V-45 insulation did not improve stability.

C.7 GENIE

References in Subsection C.7 describe the functional tests performed on aged GENIE rocket motors. In addition to evaluation of the full-scale motors, the service life of components such as igniters, O-rings, and timers, has been established.

C.8 HAWK

The shelf-life/service life of the HAWK dual thrust rocket motor, (as well as the following motor components: electric power system (EPU), initiators, ignition systems, bipropellant grain, and bonds) are reported in Subsection C.8. Tests have been conducted with units up to 5 years old.

C.9 5.0-INCH HVAR

The aging behavior of the 5.0-inch HAVR rocket motor is reported in references in Subsection C.9. These motors are still in service in both the Air Force and Navy, some units are up to 17 years old. These reports also describe the condition of field-aged motor components after disassembly. Further information on these motors may be found in the Navy Type-Life/Surveillance Programs (References C.23.1 through C.23.23). The 5.0-inch SSAR, Reference C.16.5, is included here because further information on this motor was not available.

C.10 HONEST JOHN/LITTLE JOHN

References in Subsection C.10 reports on the performance of HONEST JOHN/LITTLE JOHN rocket motors. The condition of components is also reported.

C.11 JATO'S

All references to JATO's are as References C.11.1 through C.11.49. In general, these motors are of rather simple design and some very old units are still in service. Test information on many aged motors is available. Designs include cartridge-loaded and case-bonded motors which employ a broad spectrum of components and materials. Moreover, reports are referenced which describe performance of aged components of many configurations, including propellant grains, igniters, metal parts, O-rings, plastic and metal weather seals, case bonding, inhibitors, and "as received" rocket motors. These reports will be relied on heavily

C.1 POLARIS (Continued)

C.1.7 "Polaris Development," Progress Report No. DEV 3555, 50 pp., Allegany Ballistics Laboratory, Cumberland, Maryland, 8 April 1963.

Fired one A-2 Stage II surveillance motor stored 15 months at 100°F. Performed OK for 46.9 seconds when the complete aft dome was ejected, this failure is associated with C7 adhesive used as bond material.

C.1.8 "Polaris Power Plant Development," Report No. 3791-11Q-6, November 1962-January 1963, 112 pp., Aerojet-General Corp., Sacramento, California, 28 February 1963. (C)

A 10KS-2500 motor containing ANP-2969 KH1 propellant fired successfully after 217 days accelerated aging at 150°F. Standard Isp was unchanged.

C.1.9 "Polaris Power Plant Development," Report No. 3791-11Q-3, Aerojet-General Corp., Sacramento, California, February-April 1962, 31 May 1962. (C)

1. Accelerated aging studies at 180°F and 150°F showed nitroplasticized PU propellants for A3 more stable than ANP-2639 AF used in A1 and A2 motors.
2. New aging program initiated, fabricating 13 chambers made of E-787 preimpregnated HTS glass roving; 12 will be aged from 0 to 36 months at +60°F prior to hydroburst.
3. O-rings in ambient storage since 1 November 1961 and controlled temperature storage since 1 March 1962. Six-month nondestructive and destructive tests to begin 1 May 1962.

C.1.10 "Chemistry Research," Report No. NAVWEPS 7108, Quarterly Progress Technical Report No. 115, October-December 1961, 145 pp., U.S. Naval Propellant Plant, Indian Head, Maryland, 1 February 1962. (C)

A2 Polaris; aging study of Aerojet-General Corp. propellants ANP-2639AF and ANP-2655AF (polyurethane) and Allegany Ballistics Laboratory, propellant DDP-70.

C.1.11 "Polaris Power Plant Development," Report No. 3791-11Q-2, Aerojet-General Corp., Sacramento, California, 88 pp., November 1961-January 1962, 28 February 1962. (C)

O-ring surveillance program completed. Testing unaged O-rings except for temperature retraction and permanent set. Nine O-rings of 9 types tested for tensile, elongation, and modulus; provided basis for comparison with aged O-rings.

C.1 POLARIS (Continued)

C.1.12 "Polaris Power Plant Development," Report No. 3791-11Q-1, Aerojet-General Corp., Sacramento, California, August-October 1961, 30 November 1961. (C)

Propellant aging study of Stage I and II, A3 propellants conducted at +180°F, +150°F, +110°F and +80°F. Useful life of nitroplasticized propellants at +180°F varies between 1 to 8 weeks; at +150°F appear stable for at least 90 days. Useful life at +150°F and +110°F not yet determined.

C.1.13 W.R. Kirchner, "Polaris Power Plant Development," Report No. 3520-01-M-41, Aerojet-General Corp., Sacramento, California, 20 March 1961. (C)

First-stage Polaris PTV Number 10 was fired successfully after being stored for 97 days at 80°F and for 160 days at 110°F in the horizontal attitude. A first-stage Polaris Model A aging motor No. 30 was satisfactorily fired on 12 January 1961 after 25 months of unsealed, horizontal storage; 18 months were spent at +110°F.

C.1.14 W.R. Kirchner, "Polaris Power Plant Development," Report No. 3520-01M-37, October 1960, Aerojet-General Corp., Sacramento, California, 20 November 1960. (C)

Analyses of gas samples from sealed 10-KS-2500 size motors stored at 80°F revealed only small traces of hydrogen. However, the concentration of hydrogen in one of the motors stored for 240 days at +110°F was 1.4 volume percent.

C.1.15 W.R. Kirchner, "Polaris Power Plant Development," Report No. 3520-01M-36, September 1960, Aerojet-General Corp., Sacramento, California, 20 October 1960. (C)

No significant changes in mechanical, chemical, or physical properties of ANP-2639 AF propellant were detected after 1-year storage at +80 and +110°F.

C.1.16 "Polaris Power Plant Development," Report No. 3520-01M-35, August 1960, Aerojet-General Corp., Sacramento, California, 20 September 1960. (C)

2-PAL-52—6 months of vertical storage at 110°F.

C.1.17 "Polaris Power Plant Development," Report No. 3520-01M-34, Aerojet-General Corp., Sacramento, California, 20 August 1960. (C)

Appendix B contains studies of mechanical properties and effects of aging on propellant and liners.

C.1 POLARIS (Continued)

C.1.18 "Polaris Power Plant Development," Report No. 3520-01M-33, June 1960, Aerojet-General Corp., Sacramento, California, 20 July 1960. (C)

Environmental motor, ?-PA-28, successfully fired after being aged for 18 months (12 months at +110°F).

C.1.19 "Polaris Power Plant Development," Report No. 3520-01M-32, May 1960, Aerojet-General Corp., Sacramento, California, 20 June 1960. (C)

Discusses effects of aging on mechanical properties of propellants and liner systems in appendix.

C.1.20 "Polaris Power Plant Development," Report No. 3520-01M-31, April 1960, Aerojet-General Corp., Sacramento, California, 20 May 1960. (C)

Sixty Mark 2 igniter-squib assemblies successfully withstood 7 different types of environmental tests.

C.1.21 "Polaris Power Plant Development," Report No. 3520-01M-30, Monthly No. 30, March 1960, Aerojet-General Corp., Sacramento, California, 20 April 1960. (C)

Discusses effect of aging on mechanical properties of propellants and liners.

C.1.22 "Polaris Programs," Informal Report No. 21, Naval Propellant Plant, Indian Head, Maryland, period ending 15 April 1960.

Discusses the planned surveillance program.

C.1.23 J.G. Tuono and W.M. Vogel, "The Storage Degradation of Polaris Propellant, II," Technical Memo Report No. 176, U.S. Naval Propellant Plant, Indian Head, Maryland, 12 February 1960. (C)

After storage at temperatures of 95° and 122°F, both propellant samples showed evidence of gassing and flowing. Two techniques are being used to study degradation of propellant binder.

C.1.24 J.G. Tuono, and W.M. Vogel, "The Storage Degradation of Polaris Propellant," U.S.N.P.P. Technical Memorandum Report 176, 12 February 1960. (C)

C.1.25 W.M. Vogel and J.G. Tuono, "Studies on the Thermal Degradation of Polaris Binders ANP-2639 and ANP 2655," Bulletin of 4th Meeting of JANAF Solid Propellant Surveillance Panel, December 1959.

C.1 POLARIS (Continued)

C.1.26 "Polaris Power Plant Development," Report No. 3520-01M-22, Aerojet-General Corp., Sacramento, California, 20 August 1959. (C)

Propellant aging studies were conducted. A second-stage motor was successfully fired after aging for 11 months.

C.1.27 "Polaris Power Plant Development," Report No. 3520-01M-20, Aerojet-General Corp., Sacramento, California, 20 June 1959. (C)

Propellants based on polyester 3088 and NPGA showed excellent thermal stability at 180°F. Mechanical properties of ANP-2639AF propellant have not been significantly changed by 64 weeks' storage at 80°F. First-stage PTV1-PO-10 was successfully fired after 8 months' storage. Small motors containing polyurethane propellants were stored for up to 27 months with minor or no degradation.

C.1.28 "Polaris Power Plant Development," Report No. 3520-01M-19, Aerojet-General Corp., Sacramento, California, May 1959. (C)

Aging studies were started for several different propellant systems.

C.1.29 W.R. Kirchner, "Polaris Power Plant Development," Report No. 3520-01M-16, Aerojet-General Corp., Sacramento, California, 20 February 1959. (C)

ANP-2723 HG propellant showed high thermal stability after aging for 15 weeks at +180°F. Ultrasonic inspection is being utilized to detect bond separations.

C.1.30 "Polaris Power Plant Development," Report No. 3520-01M-14, (November 1958) 90 pp., 46 figures, 21 tables, also 4 appendices including 10 figures, and 7 tables, Aerojet-General Corp., Sacramento, California, 20 December 1958. (C)

Of the 22 chamber failures occurring during hydrostatic testing, only one was due to defective material. A first-stage closure and 2 second-stage closures failed below design pressure due to defective material.

C.1.31 "Polaris Power Plant Development," Report No. 3520-01M-13, Monthly (October 1958) 93 pp., 24 tables, 57 figures, also 1 appendix including 9 tables, 2 figures, Aerojet-General Corp., Sacramento, California, 20 November 1958. (C)

Polaris Model A: Igniter difficulties due to design, not aging.

C.1 POLARIS (Continued)

C.1.32 "Polaris Power Plant Development," Report No. 3520-01M-12 (Monthly) September 1958, 120 pp., 28 tables, 26 figures, and 3 appendices, Aerojet-General Corp., Sacramento, California, 20 October 1958. (C)

Polaris Model A: data obtained from Buna O-ring material stored in a compression fixture for 26 days at 80°F show that a permanent set of 25 percent devlops under 30 percent compression. First-stage igniters containing pellets over 1-year old fire with initial high pressures.

C.1.33 Carl Boyers, et al., "The Storage Degradation of Polaris Propellant," Memo Report No. 153, U.S. Naval Propellant Plant, Indian Head, Maryland, 29 September 1958. (C)

A program has been planned with the following objectives: 1) determine manifestations of aging, 2) establish expected useful life, and 3) devise tests to indicate the remaining useful life.

C.1.34 "Polaris Power Plant Development," Report No. 3520-01M-11 (Monthly) (August 1958), 102 pp., 37 tables, 64 figures, 5 appendices, Aerojet-General Corp., Sacramento, California, 20 September 1958. (C)

Liner studies: bond strengths of SD-731 and SD-733 to Polaris A propellants decrease in 8 weeks at 180°F, but do not change appreciably during 8 weeks at 80 and 110°F.

C.1.35 "Polaris Power Plant Development," Report No. 3520-01M-10 (Monthly) (July 1958), 103 pp, and 25 tables, 43 figures, 2 appendices, Aerojet-General Corp., Sacramento, California, 20 August 1958. (C)

Liner Studies: aging of SD-733 liners show bond strengths to be unchanged by 4 weeks at 80 and 110°F, but a decrease was noted after 4 weeks at 180°F. Aerowrap Development: a 40-inch diameter Aerowrap chamber was successfully hydrostatically tested after a 3-month aging period at 170°F.

C.1.36 "Polaris Power Plant Development," Report No. 3520-01M-9 (Monthly) (July 1958) 115 pp. and 36 tables, 44 figures, 3 appendices, Aerojet-General Corp., Sacramento, California, 20 July 1958. (C)

Liner Studies: XEL-53 and XEL-91 liners showed increased strength on storage at 180°F. With storage at 80 and 110°F, the effect was slight. Aluminum honeycomb material shows that they provide as good a reinforcement at the liner-propellant interface as glass fiber mats.

C.1 POLARIS (Continued)

C.1.37 "Polaris Power Plant Development," Report No. 3520-01M-8 (Monthly) (May 1958) Aerojet-General Corp., Sacramento, California, 88 pp. and 46 tables, 49 figures, 3 appendices, 20 June 1958. (C)

Liner Studies: deterioration of SD-723 liner in less than 6 months at 110°F or above. SD-723T failed during temperature cycling at 0°F.

C.1.38 "Polaris Power Plant Program," Report No. 2214-4 (Quarterly, 15 January-14 April 1957, 15 January-14 March), vol. 1 174 pp., vol. 2 (Supplemental Data) 55 tables, 153 figures Aerojet-General Corp., Sacramento, California, 15 May 1957. (C)

C.2 ASROC

C.2.1 G.B. Booth, "Surveillance of Fleet-Return Motors Mk 1 Mod 0 and Mk 37 Mod 0," Report No. QAS/NPP 64-6, U.S. Naval Propellant Plant, Indian Head, Maryland, 16 pp., 17 August 1964. (C)

Fleet-returns of 11 ASROC Mk 1 Mod 0 (4-ES-11, 000) motors tested from NPP Lots 1, 2, 3 and 7. Purpose: determine serviceability of 2.4 to 3.4 year old motors and study aging characteristics.

Motors performed acceptably. With exception of grain shrinkage, no appreciable changes noted.

Recommends service life of ASROC Motor Mk 1 Mod 0 and Mk 37 Mod 0 be extended from 4 to 6 years.

C.2.2 R.L. Schmidt, "Investigation of Electromagnetic Radiation Hazards to the ASROC Missile (Torpedo Configuration Only) Onboard the USS Adams (DDG-2)," NWL Report No. 1763 (File No. F3932), Naval Weapons Laboratories, Dahlgren, Virginia, 5 pp., 17 May 1961. (C)

Tests show that RF energy is induced in EED switches in motor igniter and Range and Airframe Separation Programmer (RASP) but insufficient magnitude to actuate EED's.

C.2.3 G.H. Moody and V.R. Alford, "ASROC Booster (JATO X242)," ABL/MPRs 59, 61, Allegany Ballistics Laboratory, November 1956. (C)

Special attention was given to NG migrating from the propellant into the inhibitor. Fifty of 150 X2B2 ignition elements have been satisfactorily fired. A brief summary of progress in the design of inert parts is given.

C.3 BOAR MK 6 MOD 0

C.3.1 V.E. Hart and J.A. Walker, "Quality Surveillance of 5-Year Old Boar Missile Boosters Mk 6 Mod 0," Report No. QE/NPP 62-4 (File No. F3595), U.S. Naval Propellant Plant, Indian Head, Maryland, 17 pp., 30 January 1962. (C)

Three 5-year old boosters returned from fleet. No deleterious aging effects noted in chemical/ballistic performance of the Mk 37 Mod 0 grains. Performance of Mk 157 Mod 0 igniter also satisfactory.

Recommends extending service life to 8 years until yearly tests indicate deleterious aging trends.

C.3.2 "Quality Evaluation of 3-Year Old Boar Missile Boosters Mk 6 Mod 0," QEI Report No. QEI/NPP 59-5, U.S. Naval Propellant Plant, Indian Head, Maryland, 8 September 1959. (C)

Nine 3-year old fleet-returned units were subjected to quality evaluation studies.

C.3.3 M.F. Markey, "Quality Evaluation Boar Missile Booster Mk 6 Mod 0," Report No. QE/NPP 58-14, U.S. Naval Propellant Plant, Indian Head, Maryland, 2 February 1959. (C)

Thirteen boosters were tested as part of the quality surveillance program. Condition of propellant grain was excellent.

C.4 BOMARC M-51

*C.4.1 M. V. Reid, "Surveillance Testing of the M-51 Bomarc Booster Motor (Phase 2) (U)," Report No. 00Y-TR-65-108, AD 361386, X65-19095, Ogden Air Materiel Area, Hill AFB, Ogden, Utah, April 1965.

Four 40-month old boosters were tested with satisfactory results.

C.4.2 W. V. Reid, "Surveillance Testing of the M51 Bomarc Booster Motor (Phase 2)," Report No. 00Y-TR-65-108, Airmunitions Test Report, Ogden Air Materiel Area, Hill AFB, Ogden, Utah, 30 pp., April 1965.

Four M51 motors approximately 40-months old, loaded with TCC propellant TP-L-8113, successfully test fired and compared to acceptance testing.

No indication of deterioration. Based on these 4 motors minimum and maximum reliability of 47.3 and 100 percent, respectively, at confidence level of 90 percent. Best estimate of reliability is 87 percent.

C.4.3 William V. Reid, "Second Phase Ballistic Test of 5-inch Cylindrical Perforation (5-inch C.P.) Rocket Motor," Report No. 00Y-TR-65-862, Ogden Air Materiel Area, Hill AFB, Ogden, Utah, October 1965.

Surveillance program of Bomarc B Weapon System. Utilizes aged subscale motors.

C.4.4 W. V. Reid, "Shelf and Service Life Test of Rocket Motor M51 for Bomarc B Missile," Report No. 00Y-TR-64-809, Ogden Air Materiel Area, Hill AFB, Utah, 19 pp., November 1964.

First phase of long range program to verify 5-year shelf/service life. Two motors, U-116 and U-160, aged 33 and 38 months, respectively, and used in training flights. Telemetered data, P_c, indicated that both motors met model specification requirements.

C.4.5 "Service Life Test of TX53 Actuator Valve IM-99A Missile," Report No. AD 297977, Ogden Air Materiel Area, Hill AFB, Utah.

C.4.6 "Service and Shelf Life of SEV 44B Explosive Valve IM 99A," Report No. AD 406768, Ogden Air Materiel Area, Hill AFB, Utah.

C.4.7 "Service and Shelf Life of Explosive Switch P/N 1186 for T3019E5 Arming Programmer, IM 99A Missile," Report No. AD 409169, Ogden Air Materiel Area, Hill AFB, Utah.

*This reference inadvertly duplicated; see C.4.2.

C.5 FALCON (GAR 1A/2A, GAR 3A/4A, GAR 8)

C.5.1 P.P. Jennens, "Service Life of Rocket Motor Mk 17 for GAR," Report No. 00Y-TR-61-10, Ogden Air Materiel Area, Hill AFB, Utah, February 1961. (C)

Static firing tests indicated that the previously established 30-month service life could be increased to 48 months.

C.5.2 H.G. Jones, "Falcon Product Improvement Program," Final Report No. E244-60, vol. I-III, Thiokol Chemical Corp., Elkton Division, Maryland, 14 February 1961.

Studies were conducted for laboratory aging of propellants at -20, +170 and +200°F for periods of 10 days to 6 months.

C.5.3 P.P. Jennens, "Shelf and Service Life of Rocket Motor M58A2," Report No. 00Y-TR-60-16, Ogden Air Materiel Area, Hill AFB, Utah, May 1960. (C)

Tests to establish a shelf and service life for the M58A2 rocket motor. Concludes that the service life be extended from 24 to 30 months.

C.5.4 P.P. Jennens, "Serviceability of Overage Rocket Motor M58," Report No. 00Y-TR-60-5, Ogden Air Materiel Area, Hill AFB, Utah, March 1960. (C)

Tests to determine if the overage (40-41 months) Falcon M58 Rocket Motors could be utilized in training. Concludes that motors of this age are safe and reliable providing they are normally handled and fired between 0°F and 150°F.

C.5.5 W.C. Smith and C.T. Ratliff, "Progress Report of Projects in Support of USAF Falcon Guided Missile Program," 16 August - 15 November 1958, Report No. 17-59, Thiokol Chemical Corp., Redstone Division, Huntsville, Alabama, 5 May 1959. (C)

Two XM46 motors stored for 9 weeks at 140°F fired successfully.

C.5.6 W.C. Smith and C.T. Ratliff, "Progress Report of Projects in Support of USAF Falcon Guided Missile," 16 May - 15 August 1958, Report No 13-59, Thiokol Chemical Corp., Redstone Division, Huntsville, Alabama, 5 May 1959. (C)

High and low temperature storage investigations conducted on the M58 and XM46 motors.

C.5 FALCON (Continued)

C.5.7 Morton Bassin and J.M. McGarry, "Study and Improvement of Storage Capability of Solid Propellant Engines," Report No. E-151-58 (QPR No. 1) and Report No. E34-59 (QPR No. 2), Thiokol Chemical Corporation, Elkton, Maryland, 1958-59. (C)

Program objectives are: 1) to determine "weak links" in aging capability of solid propellant engines, 2) to develop means of improving aging capabilities 3) demonstrate improved storage capabilities.

C.5.8 W.C. Smith and C.T. Ratliff, "Progress Report of Projects in Support of USAF Falcon Guided Missile Program," Report No. 5-59, Thiokol Chemical Corp., Redstone Division, Huntsville, Alabama, 16 February - 15 May 1958. (C)

Thermal stability study data is given for TRX-L706 propellant.

C.5.9 W.C. Smith and C.T. Ratliff, "Progress Report of Projects in Support of USAF Falcon Guided Missile Program," Report No. 54-58, Thiokol Chemical Corp., Redstone Division, Huntsville, Alabama, 16 November 1957 - 15 February 1958. (C)

Three motors loaded with TRX-F237 propellant were successfully static tested at -60°F after storage at -20°F for 60, 90, and 99 days.

C.5.10 H.L. Barnard et al., "Progress Report of Projects in Support of USAF Falcon Guided Missile Program," Report No. 47-58, Thiokol Chemical Corp., Redstone Division, Huntsville, Alabama, 16 August - 15 November 1957.

Aging tests were conducted on several different propellant formulations.

C.5.11 C.T. Ratliff and U.E. Garrison, "Progress Report of Projects in Support of USAF Falcon Guided Missile Program," Report No. 31-57 (Quarterly), 16 November 1956 - 15 February 1957 (Contracts DA-01-021-506-ORD-393 and -395 and DA-01-021-ORD-4832), Thiokol Chemical Corp., Redstone Division, Huntsville, Alabama, 13 pp., includes 188 figures, 14 tables. (C)

Test firing results of XM59A1 engines that were stored 174 days at 140°F.

C.5.12 "Progress Report of Projects in Support of USAF Falcon Guided Missile Program," Report No. QPR No. 11-57 16 May - 15 August 1956, (Contracts DA-01-021-ORD-4832 and DA-01-021-506-ORD-393), Thiokol Chemical Corp., Redstone Division, Huntsville, Alabama, 18 pp; 24 tables, 240 figures, Huntsville, Alabama. (C)

C.5 FALCON (Continued)

Aging tests indicate that the XM58A1-type engine will perform satisfactorily in static tests at -40°F after 10 days of thermal conditioning, and after 76 to 90 days of storage at 140°F.

C.5.13 U.E. Garrison and E.M. Doyle, "Progress Report of Projects in Support of USAF Falcon Guided Missile Program," Report No. 35-56 (Quarterly), 16 February to 15 May 1956, (Contract DA-01-021-ORD-4460), Thiokol Chemical Corp., Redstone Division, Huntsville, Alabama, 138 pp., 23 tables, 170 figures. (C)

Aging programs of the XM58A1 type rocket engines. M58 igniter aging study; also XM45 and XM45E1 igniters. Storage of squibs (Du Pont S-75M-1) in an NH_3 atmosphere for 32-1/2 months show no degradation. Hangfires obtained at low temperature firing were due to low energy igniters (XM18).

C.5.14 U.E. Garrison and E.M. Doyle, "Progress Report of Projects in Support of USAF Falcon Guided Missile Program," Report No. 23-56 (Contracts DA-01-021-ORD-4460, and DA-01-021-ORD-4832, ORD Proj. TU2-2023), Thiokol Chemical Corp., Redstone Division, Huntsville, Alabama, 20 pp., 18 tables, 191 figures, 16 November 1955 - 15 February 1956. (C)

Aging of propellant, liner, igniters and squibs at temperatures ranging from -50°F to 250°F.

C.5.15 U.E. Garrison and E.M. Doyle, "Progress Report of Projects in Support of USAF Falcon Guided Missile Program," Report No. 17-56 (Contract Nos. DA-01-201-ORD-4460 and DA-01-021-ORD-4832; Ord. Proj. TU2-2023), Thiokol Chemical Corp., Redstone Devision, Huntsville, Alabama, 23 pp., 29 tables, 292 figures, 16 August - 15 November 1955. (C)

High temperature aging of propellant and liner of M9 rocket motor.

High temperature storage of modifications of T27 propellant impaired ignitability. Liner L-723 appeared to possess the best high temperature storage characteristics.

C.5.16 U.R. Garrison and E.M. Doyle, "Progress Report of Projects in Support of USAF Falcon Guided Missile Program," Report No. 15-56, Thiokol Chemical Corp., Redstone Division, Huntsville, Alabama, 18 pp., 19 tables, 128 figures, 16 May - 15 August 1955. (C)

Liner aging studies and bond inspection of the M9 rocket motor using L-721 liner.

C.5 FALCON (Continued)

C.5.17 P.J. Jennens, "Service Life Test of M58A2 Rocket Motor for GAR 1A/2A, Guided Missile (Phase V)," (U) 00Y-TR-63-1 AD 335291, Ogden Air Materiel Area, Hill AFB, Utah, March, 1963. (C)

C.5.18 "Service Life Test for the M46 Rocket Motor (GAR 3A/4A Missile), Phase II, (U) 00Y-TR-63-7, AD 335052, Ogden Air Materiel Area, Hill AFB, Utah. (C)

C.5.19 "Service Life Test of M46 Rocket Motor (GAR 3A/4A Missile) Phase III," Report No. AD 340523.

C.5.20 "Service Life Test of Mk 17 Rocket Motor for GAR 8 Guided Missile, Phase VI," Report No. AD 339131, Ogden Air Materiel Area, Hill AFB, Utah.

C.5.21 L. DeWitt et al., "A Study of Methods of Improving the Shelf Life of Solid Propellant Rocket Engines," Report No. E289-59 (Final), Thiokol Chemical Corp., Elkton Division, Elkton, Maryland. (C)

Indicates that aged-in-service M-58 engines may be serviceable for 3 years. Aged M-41 igniters were evaluated. Laboratory aging tests were conducted on various propellants.

C.5.22 P.P. Jennens, "Service Life of M58A2 Rocket Motor for GAR 1D/2A Guided Missile," Report No. 00Y-TR-61-34, Ogden Air Materiel Area, Hill AFB, Utah, September 1961. (C)

Recommends to extend service life from 38 to 48 months. Igniter shelf life was not extended.

C.5.23 P.P. Jennens, "Service Life of M58A2 Rocket for GAR 1D/2A Guided Missile," Report No. 00Y-TR-61-14, Ogden Air Materiel Area, Hill AFB, Utah, March 1961. (C)

Covers the second phase of tests conducted to determine ultimate service life for M58A2 Rocket Motors (Falcon 1.4-KS-4220). Concludes that service life should be extended to 38 months.

C.5.24 P.P. Jennens, "Service Life of M60 Rocket Motor for AIM26A/26B Guided Missile (Phase III and Phase IV)," Report No. 00Y-TR-65-161/103, Ogden Air Materiel Area, Hill AFB, Utah, November 1965.

Service life extended to 8 years.

C.6 2.25/2.75 INCH FFAR ROCKETS

C.6.1 S.A. Greenwood and W.A. Horn, "Flight Testing of Aged T207 FFAR Rockets," Report No. 3M94N1, Redstone Arsenal, Huntsville, Alabama, 7 September 1956.

C.6.2 R.V. Elliot, "General Surveillance of the 2.25 inch Rocket Motor Mk 3 Mods 2 and 3 (Mousetrap)," Report No. QE/NPP 64-9, U.S. Naval Propellant Plant, Indian Head, Maryland, 51 pp., 21 September 1964.

Tested 528 motors including critical inspection of assemblies and components, static firing at temperature extremes, igniter tests and chemical/physical analysis

Concludes general condition good but defects in igniter circuit; i.e., excess open circuits and high resistances attributed to flaked or cracked ignition lead insulation, voltage leakage at fire contact posts and corroded fin bands.

Based on ballistic, chemical/physical tests, performance will remain satisfactory until grain is 25 years old, but if igniter fails continuity check, the unit should be discarded.

C.6.3 "Service Test of XM-151 War Head for 2.75-IN. FFAR," Project USATECOM-4-4-1541-17, RDT/E-1X141806D13608, Army Aviation Test Board, Fort Rucker, Alabama, 14 October 1965.

Test Program to determine if XM-151 warhead assembled to 2.75 FFAR is suitable for use in Army helicopters.

C.6.4 "Malfunction Investigation of 2.75-Inch FFAR Lot RMHA-1060-8-55," Report No. QE/NPP 61-2, U.S. Naval Propellant Plant, Indian Head, Maryland, 10 pp., 10 January 1961. (C)

Investigation of malfunctions reported on Ammunition Lot No. RMH-1060-8-55 (sic). Nine instances of broaching and one blow during flight firings at MCAAS, Yuma, Arizona, August-September 1959. 9,772 motors loaded from this lot.

Motors met ballistic performance but showed P_c rise at tailoff. No blows. Much exudate in all motors. Chemical analysis indicated that exudate nonexplosive.

Temperature cycling -65 to +165°F. No grain damage but caused blowout discs on four igniters to eject and spill ignition material into cavity.

Recommends return to service but lower temperature from 130°F to 110°F.

C.6 FFAR ROCKETS (Continued)

C.6.5 W.E. Platt, Jr. and D.G. Peacock, "General Surveillance Evaluation of Navy Held 2.75 FFAR Motors with Mk 43 Grains," Report No. QE/NPP 61-3 (File No. F1245), U.S. Naval Propellant Plant, Indian Head, Maryland, 10 April 1961. (C)

Investigation determines, by representative sampling, the condition and probable remaining service life of FFAR motors. Trend analyses indicate that no dangerous conditions should develop on units up to 9 years old.

C.6.6 N.E. Parsons, "2.75-Inch FFAR Motors Storage and Ballistic Performance Test," Report No. AAED 3091 (File No. F2758), Royal Canadian Air Force, Central Experimental and Proving Establishment, May 1960. (C)

Five year storage tests were run on the 2.75-Inch FFAR motor. Static firing results showed that the rocket motors remained serviceable.

C.6.7 D.E. Folsom and A. Michelson, "Fourth Interim Report of Quarterly Flight Surveillance Test of 2.75-Inch FFAR Motors," Report No. QEI/NPP 59-3, 17 June 1959. (C)

A summary and analysis of quarterly surveillance flight test firings.

C.6.8 D.E. Folsom and A. Michelson, "Third Interim Report of Quarterly Flight Surveillance Tests of 2.75-Inch FFAR Motors," Report No. QE/NPP 58-12 (Third Interim Report), U.S. Naval Propellant Plant, Indian Head, Maryland, 6 pp., include 2 tables, also 3 appendices, 17 November 1958. (C)

A summary and analysis of quarterly surveillance flight-test firings at -65° and 150°F through December 1957.

C.6.9 D.E. Folsom, "Second Interim Report of Quarterly Flight Surveillance Tests of 2.75-Inch FFAR Motors," Report No. QE/NPF 57-8, Naval Powder Factory, 17 pp., includes 7 tables, numerous appendices, 20 December 1957. (C)

Quarterly surveillance flight-test firings at -65°, 130°F, and 150°F.

C.6.10 S. Skolnik, "Annual Report 1955," Report No. 2, U.S. Naval Powder Factory, 287 pp., 29 February 1956. (C)

Experimental igniters were evaluated and age tested for the Naval Ordnance Laboratory. Investigations were made of rocket malfunctions. A surveillance program was initiated using the Mk 31 Mod 1 grain for the 2.75-inch FFAR.

C.6 FFAR ROCKETS (Continued)

C.6.11 E.S. Johnson, "Special Quality Evaluation of 2.75-Inch FFAR Rocket Motors Mk 2 Mod 0 Lot RMHA 259-5-53," Report No. QE/SB 56-2, Naval Ammunition and Net Depot, Seal Beach, California, 10 pp., 13 tables, 13 figures, 3 appendices, 6 February 1956.

C.6.12 W.F. Hartzell, et al., "Development Testing and Production of a 2.75-inch Forward-Firing Rocket Using Aeroplex Propellant," Report No. 541 (Final), Aerojet-General Corp., 255 pp., numerous tables and figures, 22 January 1952. (C)

Temperature cycling, drop and vibration tests of Aeroplex 2.75-inch FFAR motor showed no deleterious effects on any of the components.

C.6.13 W.E. Platt, Jr., "Malfunction Investigation of 2.75-Inch Folding Fin Aircraft Rocket Motors, Ammunition Lot RMHA-888-S-55.1," Report No. QE/NPP 62-7, U.S. Naval Propellant Plant, Indian Head, Maryland, 19 pp. (C)

Eighty-three (83) 2.75-inch FFAR's tested because of reported erratic flights. All units inspected with particular attention to igniters, nozzles and fin assemblies. Forty motors fired "as received" at -65°F, 70°F and 130°F. One motor exploded. Attributed to grain crack.

Additional 158 motors disassembled, inspected, reassembled and fired at 3 temperatures.

Recommend return of the lot to the fleet.

C.7 GENIE

C.7.1 T.R. Bruce, "Operational Qualification of Rocket Motor MD-1 for the MB-1 Rocket," Report No. 00Y-TR-61-15 (File No. F908), Ogden Air Materiel Area, Hill AFB, Utah, March 1961. (C)

Functional tests of Rocket Motor MD-1 for the "Genie" MB-1 rocket to determine if operational motors would perform within the model specification at low temperature limits. Recommends that the operational temperature limit be raised to 0°F and the shelf life extended to 24 months.

C.7.2 D.E. Sheley, "Environmental, Functionability and Service Life Test of Rocket Motor MD-1 for the MB-1 Rocket," Report No. 00Y-TR-60-7, Ogden Air Materiel Area, Hill AFB, Utah, May 1960. (C)

Functional and firing tests for the MD-1 motor for the Genie MB-1 Rocket. Concludes that the operational shelf life of 18 months could not be extended.

C.7.3 P.P. Jennens, "Service Life Test of Rocket Motor, MD-1," Report No. 00Y-TR-60-6, Ogden Air Materiel Area, Hill AFB, Utah, April 1960. (C)

Recommends that the service life of the MD-1 rocket motor (Genie) remain at 18 months.

C.7.4 S. Goldhagen and D. Holly, "Study Methods of Improving Shelf Life of Existing and Contemplated Solid Rocket Motors," Report No. 0217-01Q-2, October-December 1958, Aerojet-General Corp., Sacramento, California, 8 pp., 11 tables, 9 figures and 1 appendix, 20 April 1960. (C)

18-month-old MD-1 motors were inspected and test fired. One motor malfunctioned at -30°F static test firing but indicated that this was not due to aging.

C.7.5 S. Goldhagen and D. Holly, "Study Methods of Improving Shelf Life of Existing and Contemplated Solid Rocket Motors," January-March 1958, Aerojet-General Corp., Sacramento, California, 20 April 1959. (C)

18-month-old MD-1 motors were received and inspected. Mechanical property measurements of propellants indicated good aging properties. Liner to propellant bonds appeared satisfactory. Some ignition delay.

C.7 GENIE (Continued)

C.7.6 D. E. Sheley, "Report of Test on Service Life Test of Rocket Motor, MD-1 for Training Use," Report No. 00Y-TR-60-14, Ogden Air Material Area, Hill AFB, Utah. (C)

Functional tests of the rocket motor MD-1 for the Genie MB-1 rocket to determine if the 20-month service life could be extended. Concludes that the shelf life for training motors could be extended to 24 months within firing temperature limits of 30°F to 140°F.

C.7.7 J.E. Watts, "Shelf and Service Life Test of Genie Rocket Motor A/A44A-1," 00Y-TR-63-2, AD 334723, Ogden Air Material Area, Hill AFB, Utah, February, 1963.

C.7.8 "Test Firing of Aged A/A44A-1 Rocket Motors, Genie Project, 00Y-TR-64-888," Report No. X64-19976, Ogden Air Material Area, Hill AFB, Utah.

C.7.9 "Service Life Test of Igniter MA-1 for MB-1 Rocket," Report No. AD 410579, Ogden Air Material Area, Hill AFB, Utah.

C.7.10 "Serviceability Test of Timer for the MB-1 Rocket," Report No. AD 336070, Ogden Air Material Area, Hill AFB, Utah.

C.8 HAWK

C.8.1 A.W. Kwett, "Hawk Motor Shelf-Life Determination Program," Final Report, Aerojet-General Corp., Sacramento, California, Report No. 0"24-07F, Contract No. DA-04-200-AMC-4(Z), 15 October 1965. (C)

The shelf-life of the XM22E8 Hawk motor can be extended to 7 years. Initiators should be inspected for continuity and for pin-to-case short circuits at the time of missile rebuild or other routine maintenance operations.

Recommends that the aging program be continued to determine any possible degradation.

Some problem areas were noted:

a. Six of twenty motors were unbonded

b. One ignition delay in twenty motors, due to pin-to-case short circuit.

C.8.2 J.A. Watts, "Report on Test of Service Life Test on Hawk Missiles." Final Report, September 1961 - June 1965, Report No. WSMR - AMTED HAWK-66-17, AD 366611L, Army Missile Test and Evaluation Directorate, White Sands Missile Range, New Mexico, September 1965. (C)

C.8.3 N.S. Gorman, et al., "Surveillance Characteristics of EPU Hawk Fuel (U)," Report No. PA-TM-1647, AD 3652039, Raytheon Company, Bedford, Massachusetts, July 1965. (C)

C.8.4 W. Hartman, "Hawk Motor Shelf-Life Determination Program," Final Report, Aerojet-General Corp., Report No. 0724-05F, Contract No. DA-04-200-AMC-4(Z), 29 July 1964. (C)

Initial 3 year shelf-life of the XM22E8 Hawk motor changed to 4 years. Recommended that the yearly testing of aged motors be continued to discover any degradation.

Several problem areas were noted:

1. Five of 24 motors had liner unbonding.
2. Seven of 24 motors had overheating in the forward end of the motor due to buckling of the projection, an assembly problem.
3. Three initiators had discontinuity of the bridgewire circuit due to corrosion of the contact pins.
4. Long ignition delay of one motor due to damage of the igniter by rough handling of the motor on shipment.

C.8.5 R.E. Rehm, "Static Test Firing Phase-Hawk XM22E5 Prequalification Program," Report No. SRP155, Aerojet-General Corp., Sacramento, California, 13 April 1959. (C)

Cracks detected in a booster grain stored at -40°F.

C.9 5.0-INCH HVAR

C.9.1 V.A. Carbone, "Surveillance Evaluation of 5.00-Inch HVAR Motors Mks 2 and 10," Report No. QAS/NPP 65-23, U.S. Naval Propellant Plant, Indian Head, Maryland, 49 pp., 9 July 1965.

The 5.00-inch HVAR (JPN cruciform partially inhibited grain) samples consisted of 680 motors ranging in age from 9 to 17 years. Some change in ballistics, particularly ignition delay. Propellant retained acceptable chemical and physical properties.

Excessive P_c maximum in motors loaded at Naval Ammunition Depot, McAlester in 1953 attributed to unbonding of inhibitor.

Cracked grains detected in U.S. Naval Propellant Plant, production not defined. Subject of special investigation.

Recommend: (1) Lots suspected of inhibitor unbond be restricted from service; (2) Lots with grain cracks be restricted pending findings of special investigation; (3) remaining 5.00-inch HVAR motors extended to 20 years.

C.9.2 D.F. Woods and T.A. Hohman, "Serviceability of 5-Inch HVAR Mk 10 Mod 7 Rocket Motors," Report No. OOY-TR-62-25, Ogden Air Materiel Area, Hill AFB, Utah, 45 pp., November 1962. (C)

Air Force stocks of 5.0-inch HVAR motors manufactured in 1953 evaluated. Static firings at -10° and 140°F. Firings at -10°F gave high P_c versus time integrals, high maximum P_c. All motors fired without incident.

Motors definitely degrade with age, but not too great to discontinue. Recommend extend service life to 12 years, but retire any HVAR exceeding 140°F.

C.9.3 J. Nanigian, "Procedures for the Quality Evaluation of 5.0-Inch HVAR Rocket Motors," QE/NPF 56-7, U.S. Naval Powder Factory, 4 pp., numerous appendices, 23 July 1956. (C)

A detailed program to estimate performance and safety characteristics of the Navy-held stock of 5.0-inch HVAR rocket motors.

C.9.4 T.H. Braunstein and S.S. Stolarz, "An Evaluation of 5.00-Inch Mk 4 Mod 1 Rocket Motors in Navy Storage Facilities," Report No. 11, Naval Powder Factory Quality Control, 55 pp., 22 June 1956. (C)

A sample of 35 5-inch Mk 4 Mod 1 rocket motors was randomly selected from each of 25 lots. Motors from each of these lots were static fired (motors were approximately 5 years old) at 140°F and -10°F. The remaining units were disassembled and individual components examined. Motors recommended for continued service.

C.9 5.0-INCH HVAR (Continued)

C.9.5 E.S. Johnson, "Quality Evaluation of 5.00 inch SSR Motors MKS 3, 4, and 5 (NM Guam Stocks)," Naval Ammunition and Net Depot, Seal Beach, California Report No. QE/SB 57-INPF (RM), 5 pages, 17 tables, 6 figures, 12 April 1957.

5.0 inch SSR Motor Mk Nos. 3, 4, and 5 stored at Guam at tempertures in excess of 130°F were tested.

C.10 HONEST JOHN/LITTLE JOHN

C.10.1 "Status of Development Projects," ABL/QPR-42, 16 October 1962-15 January 1963, Allegany Ballistics Laboratory, Cumberland, Maryland, 78 pp., 15 February 1963. (C)

Six 1-year XM31E3 (Improved Honest John) units statically fired. Ballistic data indicated only slight change during first year of mobilization stockpile storage. Two motors were out of specification. Not defined if this altered performance can be tolerated in flight tests.

Static firing of four 2-year and four 3-year old XM31E3 rocket motors. Initial progressivity attributed to low burning rate on propellant surface. Postulated that this was due to plastizer (NG and TA) evaporation from propellant surface. Four grains exposed to atmosphere.

C.10.2 "Status of Development Projects," ABL/QPR-38, 16 April-15 July 1962, 3.3-DS-109,000 Rocket Motor, XM31E3, SM24483, Alleghany Ballistics Laboratory, Cumberland, Maryland, 62 pp., 15 August 1962. (C)

Two-year motors tested. Six motors fired and one motor chemically and physically analyzed.

Ballistic performance normal except extra burn surface on two -40°F rounds caused by partial delamination of inhibitor. Resulted in P_c maximum increasing above specification.

C.10.3 "XM26 Phase I Little John Surveillance Data," Letter Report, HPC, Radford Arsenal, Virginia, 19 October 1961.

Reports on ballistic, chemical and mechanical properties of propellant.

C.10.4 "Final Report, Quality Assurance Investigation 1154, Testing Long Term Storage, Phase I Little John Motors," Letter Report, HPC, Radford Arsenal, Virginia, 23 August 1961.

C.10.5 "Serviceable Shelf Life Program FY61 Honest John M3," Letter Report, HPC, Radford Arsenal, Virginia, 31 May 1961.

Reports results of unloading, inspecting and reloading of component parts and grains of aged M3 rocket motors.

C.10.6 NO TITLE, Subject: Shelf Life of M6 and/or M6A1 Honest John Rocket Motors, Letter Report, HPC, Radford Arsenal, Virginia, 24 June 1960. (C)

Describes condition of motor and components of aged M6 and M6A1 rocket motors.

C.10 HONEST JOHN/LITTLE JOHN (Continued)

C.10.7 "Cast Double-Base Propellant and JATO Development," Allegany Ballistics Laboratory, Cumberland, Maryland, ABL/MPR 65, 15 January-15 February 1957, 101 pp., including 29 tables, 35 figures. (C)

S. Little John, JATO Unit XM-26 (X235A2). Chamber failures obtained at -40°F static firings.

C.10.8 J. Abel III and B.B. Grallman, "Static Test Firings of M7A1 Rocket Motors," Technical Note No. 1507, Ballistic Research Laboratories, Aberdeen Proving Grounds, Maryland, 47 pp. (C)

Tested 184 rounds of M7A1 (Honest John Spin Motor) from 6 lots. Some erratic P_c and F records. X-ray indicated 3 types of flaws: voids, grain cracking, and separation of grain from headend of motor.

There was no correlation between flaws detected by X-ray and erratic P_c and F tracers.

C.11 JATOS

C.11.1 J.J. Canavan and A. Goldstein, "Ten-Year Age Test, Mk 2 Mod 3 (14-AS-1000) JATO, U.S. Naval Air Rocket Test Station NARTS 98 (TN), 5 pp., 2 appendices, February 1957.

Thirty-three Mk 2 Mod 3 (14-AS-1000) JATOS, stored for 10 years were internally inspected, temperature conditioned and static fired for the final phase of a long-term storage study.

C.11.2 J.J. Canavan, "Age Tests of Mark 2 Mod 3 (14-AS-1000) JATOS," Naval Air Rocket Test Station NARTS 75 (Report), 9 pp., 10 figures, 3 tables, December 1955.

Nine year storage of 34 Mk 2 Mod 0 (14-AS-1000) JATOS and temperature-conditioning at -10° to 140°F.

C.11.3 L.M. Singer, "Reliability Test of 2.2KS-11000 Rocket Motors with Plastic Pressure Diaphragms and Modification of the Grain," Report No. OOY-TR-62-19 (File No. F5101), Ogden Air Materiel Area, Hill AFB, Utah, 24 pp., September 1962.

Tested 17 motors 12-28 months old. 7 motors showed axial thrust above specification whereas the ∫ Fdt of 6 of the 7 was within specification limits.

Tests also show that 1/8 - 3/8 inch dents on outer edge of exit cone did not produce significant side thrust but dents and bulges at or near the nozzle throat produced more marked side thrust.

C.11.4 W.A. Poole, "Shelf Life and Serviceability Tests of JATOS Rocket Motors 14-DS-1000 (Mk 4 Mod 2) 15-KS-1000 (Mk 6 Mods 1 and 0) 16-NS-1000 (M15 and M15A1)," U.S. Naval Propellant Plant, Indian Head, Maryland, 195 pp., 16 August 1965.

C.11.5 G.H. Kowaniski, "Shelf Life and Serviceability Test of Rocket Motor 14-DS-1000," Report No. OOY-TR-65-850, Ogden Air Materiel Area, Hill AFB, Utah, 6 pp., February 1965.

Motors 10-11 years old inspected. Temperature conditioned and static tested. Tested by U.S. Naval Propellant Plant, Indian Head, Maryland. The Mk 153 igniter deteriorates at temperatures above +120°F.

Recommends: 12 year shelf life on motors and igniters with temperature limits of -10° to +120°F.

*C.11.6 G.H. Kowaniski, "Shelf Life and Serviceability Test of Rocket Motor 14-DS-1000," Report No. OOY-TR-65-850, AD 456689, X65-15085, Ogden Air Materiel Area, Hill AFB, Utah, February 1965.

*This reference inadvertably duplicated, see C.11.5.

C.11 JATOS (Continued)

To confirm 10 year shelf life of motor, motors were examined at 10 years, 5 month to 11 years old and the shelf life was extended to 12 years. Problems with igniters stored over 120°F.

C.11.7 G.H. Kowaniski, "Serviceability Test for Rocket Motor 14-DS-1000, Mk 4, Mod 2 and M8 Models," Report No. OOY-TR-64-759, Ogden Air Materiel Area, Hill AFB, April 1964. (C)

Program to determine if shelf life could be extended by establishing new low temperature limits. Samples from 91 to 116 months. Motors exhibit afterburning phenomenon at -30, -20, and -10°F. Performance satisfactory during firing.

Recommend: Extend shelf life to 10 years and temperature limits of -10 to +140°F.

C.11.8 R.T. Mazinski, "Effects of Storage on the T1 JATOS Jet Propulsion Unit 1.5-ES-600," Report No. 2241 (Ord proj. TU2-4D, Item 16, 31 pp., 10 tables, 6 figures, Picatinny Arsenal, Dover, N. J., November 1955. (C)

Effects of storage for nine years in a typical field service depot on the JATOS 1.5-ES-600, T1. Deterioration of igniter cords, due to nitroglycerine migration, was noted.

C.11.9 W.F. Lehman, "Evaluation of Grand Central 15-Sec, 1000 lb-Thrust Ammonium Nitrate JATO," Report No. 63 (BuAer Proj. TED-ARTS-51-5208), Naval Air Rocket Test Station, Lake Denmark, 27 pp., 7 tables, 30 figures, 4 appendices, June 1955. (C)

Results of evaluation tests carried out on 66 fifteen-second, 1000 lb-thrust JATOS, including environmental testing.

C.11.10 V.E. Hart and W.E. Platt Jr., "Quality Surveillance of Aircraft JATO Units Mk 2 (5KS-4500)," Report No. QE/NPP 62-6, (File No. F5437), U.S. Naval Propellant Plant, Indian Head, Maryland, 29 pp., 27 September 1962. (C)

Test of 112 units. Units were manufactured from 1954 to 1959. Recommended: (1) no change in unlimited shelf life (2) tensile tests for propellant acceptance be introduced (3) quality control procedures be tightened. In addition, because of minor corrosion problems-corrosion-prevention maintenance procedures should be emphasized.

C.11.11 W.F. Lehman, "Test Firings of Mk 7 Mod 1 (5-KS-4500) JATOS Mishandled During Service Use," NARTS 81 (Tech Note), U.S. Naval Air Rocket Test Station, 5 pp., 1 table, 6 figures, November 1956. (C)

C.11 JATOS (Continued)

Nine Mk 7 Mod 1 (5-KS-4500) JATOS were dropped one foot. On scene investigation and a later internal inspection before firing showed no visible damage.

C.11.12 F.G. Lachnitt, "Development of 5 NS-4500 (Formerly 5 KS-4500) Single-Grain Solid-Propellant JATO Rocket," Reports L2234/35-1, -2, L2799-3 thru -6, Aerojet-General Corp., Sacramento California, October 1956. (C)

Major categories of work involved designing of inert components to simplify manufacturing, reducing weight and improving performance, designing and developing an improved grain, designing and developing an improved igniter, and environmental testing including temperature cycling, vibration, impact, acceleration and static test firing.

C.11.13 R.M. Cavett, "Shelf Life Test on Rocket Motors, 15KS-1000, Mk 6 Mods," Report No. 00Y-TR-63-4, Hill AFB, Utah, 21 pp., February 1963. (U)

Establishes ultimate life of 15KS-1000 motors - 24 motors visually and X-ray inspected and fired. Temperature extremes of 150°F and -75°F. Motors continued to function without incident, but data drift toward specification limits.

Recommends established 9 year life, extend shelf life to 10 years.

C.11.14 S.H. Welch, "Serviceability Tests of Leached Rocket Motors 15KS-1000, Mk 6 Mods 0 and 1," Report No. 00Y-TR-61-11, Ogden Air Materiel Area, Hill AFB, Utah, February 1961. (C)

Serviceability was determined of rocket motors, 15KS-1000, which contain crystals on the surface of the grain. It was recommended that these motors be retained in serviceable status.

*C.11.15 R.M. Cavett, "Shelf Life Test on Rocket Motors 15KS-1000 Mk 6 Mods," Report No., 004-TR-63-4, AD 296301, Ogden Air Materiel Area, Hill AFB, Utah, February 1961.

C.11.16 D.F. Woods and S.H. Welch, "Serviceability of Rocket Motor 15-KS-1000 Mk 6, Mods," Report No. 00Y-TR-60-13, Ogden Air Materiel Area, May 1960. (C)

Motors returned from Lajes Field, Azores were inspected and static fired. All 24 motors were unserviceable.

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*This reference inadvertably duplicated, see C.11.13.

C.11 JATOS (Continued)

C.11.17 N.E. Parsons, "JATO Unit Model 15KS-1000 Prolonged Storage and Sampling Test," Report No. AAED 3088 (File No. F2757), Royal Canadian Air Force, Central Experimental and Proving Establishment, May 1960. (C)

JATO units placed in field storage in October 1954 and statically fired during the period October 1956 to March 1960. Data indicated that the JATO units remained serviceable.

C.11.18 G.M. Taylor, "Age Tests of 15-KS-1000 JATO," Report No. 1628, U.S. Naval Proving Ground, Dahlgren, Virginia, 7 pp., 13 November 1958. (C)

Twenty 15-KS-1000 Mk 6 Mod 0 JATO units and 20 Mk 165 Mod 0 igniters were static fired to evaluate the effects of 5 years storage in Cuba and in Alaska.

C.11.19 "Solid Propellant Aging Studies," Report No. AR(752)-1-59, Astrodyne, Inc., McGregor Texas, 1 April 1959. (C)

Experiment on aged-in-service M15 JATO motors. Closed vessel aging tests on motor components representative of M15A1, XM-34 and Retrorockets. A trend toward embrittlement of rubber O-rings was noted.

C.11.20 "Solid Propellant Aging Studies," Report No. AR(752)-2-58, Astrodyne, Inc., McGregor, Texas, 1 January 1959. (C)

Tests aged-in-service motors and igniters, and closed vessel aging of motor components. M15 JATOS, Retro, and XM-34 motors involved.

C.11.21 "Solid Propellant Aging Studies," Report No. AR(752)-1-58, Astrodyne, Inc., McGregor, Texas, 1 October 1958. (C)

Evaluates aging characteristics of propellant and igniters for M15 JATOS, Retro and XM-34.

C.11.22 H.C. Schindler, "Two Years of Arctic Surveillance of the M13 (Matador), M5 (Nike) and M6 (Honest John) JATOS," Tech. Report No. 2670, Picatinny Arsenal, Dover, New Jersey, January 1959. (C)

JATOS were stored for 2 years under artic outdoor storage conditions. Some rust formed and polyethylene closure of T40 igniter cracked.

C.11.23 H.C. Schindler and J.J. Confides, "Effects of Magazine Storage on the T50 JATO (U)," Technical Report 2533, Picatinny Arsenal, Dover, New Jersey, 19 pp., includes 5 figures and 3 tables, Au 1958. (C)

C.11 JATOS (Continued)

Two 2.4-KS-57,000 T50 JATO's stored for 45 months in an igloo to determine the effects of such storage.

C.11.24 L.E. Latimer, "Static Test of One JATO, XM16E1 Aged for Two Years-Round No. A-3," Report No. 3M64N12, Redstone Arsenal, Huntsville, Alabama, 6 January 1958. (C)

Data from one test in a 5 year aging program.

C.11.25 W.F. Lehman, "Second Annual Age Test of JATOS Mk 6 Mod 0 and Igniters Mk 165 Mod 0," Naval Air Rocket Test Station Technical Note 99, 9 pp., 4 tables, 3 figures, April 1957. (C)

Two groups of Mk 6 Mod 0 JATOS and Mk 165 Mod 0 igniters, stored at Kodiak, Alaska and Guantanamo Bay, Cuba—to determine how performance was affected by two years storage.

C.11.26 W.F. Lehman, "First Annual Age Test of JATOS Mk 7 Mod 0 and igniters Mk 166 Mod 0," Naval Air Rocket Test Station NARTS 100 (Report), 15 pp., including 9 figures, April 1957. (C)

JATOS Mk 7 Mod 0 (5-KS-4500) and Mk 166 Mod 0 igniters tested for effects of age under arctic cold and tropical heat and humidity.

C.11.27 "Cast Double Base Propellant and JATO Development," Alleghaney Ballistics Laboratory, Cumberland, Maryland, ABL/MPR 65 (15 January to 15 February 1957, 101 pp., including 29 tables, 35 figures, 1 March 1957.

Storage of 30 JATO X220 grains of case bonded ATN propellant. Effects of storage of precoated chambers on bonding properties of case-bonding adhesive.

C.11.28 W.F. Lehman, "First Annual Age Test of JATOS Mk 6 Mod 0 and Igniters Mk 165 Mod 0," Report No. 91 (Proj. TED-ARTS-SI-5206), Naval Air Rocket Test Station NARTS, 32 pp., 8 tables, 13 figures, July 1956. (C)

Two groups of Mk 6 Mod 0 JATOS with Mk 165 Mod 0 igniters, stored at Kodiak, Alaska, and Guantanamo Bay, Cuba, tested for effects of age under artic cold or tropical heat and humidity. They were static fired.

C.11.29 C.M. Mitchell and D.B. Myers, "Phase Report; Qualification Test Program, XM16E1 Solid Propellant Rocket Engine," Report No. 11-56 (Ord. Proj. TU2-2030, USAF Proj. 3-49), Thiokol Chemical Corp., Redstone, Alabama, 24 pp., 7 tables, 98 figures, May 1956. (C)

C.11 JATOS (Continued)

Qualification test for XM16E1 solid propellant engine. Rain and salt spray tests, temperature cycling, vibration, altitude cycling, drop tests, accelerated aging tests; fired under various conditions. No failures.

C.11.30 C.M. Mitchell and D.B. Meyers, "Appendices to Phase Report; Qualification Test Program XM16E1 Solid-Propellant Rocket Engine," Report No. S11-56 (Ord. Proj. TU2-2030, USAF Proj. 3-49), Thiokol Chemical Corp., Redstone, Alabama, 4 appendices, numerous tables and figures, May 1956. (C)

Supplemental report to Report No. 11-15 containing information and data pertaining to the qualification testing of the XM16E1 rocket engine.

C.11.31 H.C. Schindler and J.J. Confides, "Effects of 4 Years Storage in an Open Revetment on the M13 (T50) JATO," Technical Report No. 2630, Picatinny Arsenal, Dover, New Jersey. (C)

Two M13 JATOS which had been stored for 4 years in an open revetment at Weisbaden, Germany were examined and successfully fired.

C.11.32 G.H. Kowaniski, "Surveillance Test of Shelf Life of Rocket Motor, 16NS-1000, M-15," Report No. 00Y-TR-64-761, Ogden Air Materiel Area, Hill AFB, Utah, 19 pp., May 1964.

Previous temperature limits were -20 to +130°F for motors aged 5-7 years. Tested to determine if age could be 8 years.

72 motors from field storage tested. 33 conditioned at -30°F and performed satisfactory. 7 fired after conditioning at 140°F failed because of excessive P_c - one motor ruptured relief disc. Of 3 motors fired at 130°F one relief disc failed. 25 motors conditioned at 120°F and performed satisfactory.

Concludes 16NS-1000, M-15 rocket motor will perform satisfactory at 8 years between -20 and +110°F.

C.11.33 R.M. Cavitt, "Service Life Test of Rocket Motors, 16NS-1000, M15 and M15A1 with Igniters Installed," Report No. 00Y-TR-63-9, Ogden Air Materiel Area, Hill AFB, Utah, 23 pp., March 1963.

Test to determine if 16NS-1000, M15 and M15A1 rocket motors are serviceable after being on alert status 28 months.

50 motors 49-56 months old inspected temperature conditioned and fired at -75, +70 and +170°F. 6 motors deviated slightly from specification. Others satisfactory.

Demonstrates that motors 49-56 months are serviceable after 28 months alert status.

C.11 JATOS (Continued)

C.11.34 R.M. Cavett, "Safe Operating Temperature Limits and Shelf Life of Rocket Motors, 16NS-1000, M15," Report No. 00Y-TR-62-23, Ogden Air Materiel Area, Hill AFB, Utah, October 1962.

Program to determine new temperature limits on 16NS-1000, M15 rocket motor up to 7 years old as suitable for training purposes.

Total of 198 motors inspected visually and X-rayed, temperature conditioned and fired. 2 motors of 39 failed at -40°F. 71 motors fired successfully. 88 motors fired successfully at 140°F.

Recommends changing temperature limits to -20 to +130°F for motors not over 7 years old.

C.11.35 R.M. Cavett, "Serviceability and Shelf Life Test of Rocket Motors, 16NS-1000, M15, with Igniters," Report No. 00Y-TR-62-13 (File No. F4896), Ogden Air Materiel Area, Hill AFB, Utah, 27 pp.

Total of 70 motors inspected, conditioned, and fired. Results 8 motors failed, one hang-fire at -50°F and 7 motors with high P_c max. Partial successes: 11 motors at -50°F, 3 at 70°F, and 9 at -50. Remaining 39 units fired satisfactorily.

Recommends shelf life be reduced from 6 to 5 years.

C.11.36 R.M. Cavett, "Environmental and Functionality Tests of Rocket Motors, 16NS-1000, M15, with Igniters," Report No. 00Y-TR-61-50, (File No. F3138), Ogden Air Materiel Area, Hill AFB, Utah, 23 pp., December 1961.

54 16NS-1000 JATO motors tested at—75, 70, and 170°F to assess reliability—motors 57-60 months old (28 months environmental storage). Firings at 70 and 170°F generally satisfactory. At -75°F 13 motors satisfactory, 5 motors hang fire, two did not ignite and 4 igniters ejected from motors.

Recommend do not extend shelf life to 6 years. Further problem definition required.

C.11.37 R.M. Cavett, "Serviceability of Rocket Motors 16NS-1000, M15 and M15A1, with Igniters on Alert Status, for 12 Months," Report No. 00Y-TR-61-13, Ogden Air Materiel Area, Hill AFB, Utah, April 1961. (C)

To determine serviceability of Rocket Motors, 16NS-1000, M15 and M15A1 which were on alert status for twelve months. No unsatisfactory conditions.

C.11 JATOS (Continued)

C.11.38 S.H. Welch, "Serviceability of Unopened Rocket Motors," Report No. OOY-TR-61-5, Ogden Air Materiel Area, Hill AFB, Utah, 28 pp., January 1961. (C)

Determines serviceability of 16NS-1000, M15 and M15A1 motors as a result of malfunction causing crash of B47.

Test samples of 1204 motors from 42 lots tested along with 1206 igniters from 54 lots. 20-54 motors from each lot and 1-75 igniters from each lot tested.

Ballistic performance within design specification.

Recommends motors on which the hermetically sealed shipping plug has not been opened for ignition installation are serviceable.

Igniters using the B-73 formulation pellets are of doubtful reliability and should not be used.

C.11.39 R.E. Davis and L.B. Loehr, "Design and Development of 40-NS-4500 JATO," Report No. 815 (Supplement), Aerojet-General Corp., 30 pp., 3 tables, 20 figures, 20 August 1954. (C)

Development of an igniter to operate at low temperatures with a maximum ignition interval of 2 sec. Excessive ignition delays with alclo were encountered and it was recommended that investigations be extended to cover easily ignitable coatings applied to the propellant surface.

C.11.40 C.G. Campbell, et al., "Design and Development of 40-NS-4500 JATO," Report No. 815 (Final - Item I), Aerojet-General Corp., 331 pp., 52 tables, 195 figures, 24 May 1954. (C)

Reliability testing of 40-NS-4500 JATO includes temperature cycling between -75° to 170°F, drop tests and vibration testing. This JATO is intended for takeoff assistance for the B-52 bomber.

C.11.41 "Current Recommendation Service Life Listing for Rockets, JATO's etc.," AD36542, U.S. Naval Propellant Plant, Indian Head, Maryland, 9 September 1965. (C)

C.11.42 E.B.W. Kerone, "General Surveillance Evaluation of the 5.25 Inch Weapon A Propulsion Unit, NOTS Model 118E and Mk 2 Mod 0," Report No. QE/NPF 63-6, U.S. Naval Propellant Plant, Indian Head, Maryland, 42 pp., 28 November 1963.

Inspected and tested 114 motors from two populations. Found in good condition chemically and physically but electrical contacts corroded.

Recommends units serviceable for 9 years provided electrical contacts visually inspected immediately prior to issue.

C.11 JATOS (Continued)

C.11.43 J.M. Glessner and W.V. Day, JATO X232 (Weapon A), ABL/MPR 51, 53 (Contract NOrd 10431), Allegany Ballistics Laboratory, Cumberland, Maryland, March 1956. (C)

Six igniters for the JATO X232 were stored at high temperature (165°F) for 2, 4 and 6 week periods and four were vibrated; no adverse effects were apparent.

Three JATO X232B2 grains, each loaded in a different manner but all stored at 165°F for five weeks, showed inhibitor deterioration. In a unit using a new type of snap ring and drop tested one foot at -30°F, no damage occurred to head or metal parts.

C.11.44 D. Eliezer, et al., "Evaluation of Blowback in the 3.5 Inch Rocket M28A2," Report No. DB-TR: 4-61, June 1961.

Concluded that blow back was attributed to design, not age. However, bridgewire resistance below acceptance limits.

C.11.45 H.C. Schindler and J.J. Confides, "Effects of 5 Years Magazine (55°F) and Elevated Temperature (122°F) Storage and 6 months Cyclic Storage on the 3.5 Inch M28A2 Rocket," Technical Report No. 2635, Picatinny Arsenal, Dover, New Jersey, May 1961. (C)

A 10-year surveillance program. Results of static and flight tests after 5 years storage under elevated temperature conditions indicate no deterioration.

C.11.46 "JATO, Self-Destroying, T48E3 for Nike 1 Missile," Universal Moulded Products Report, 46 pp., 3 appendices, 15 November 1956. (C)

A manual containing a general description of the booster, the self-destroying system and surveillance and handling tests.

C.11.47 "Shelf and Service Life Test of Rocket Motor M16E3 for MACE ITM-761," Report No. AD 403924, Ogden Air Materiel Area, Hill AFB, Utah.

C.11.48 A.T. Arbon, "Shelf and Service Life Tests of Rocket Motors M16E3 for MACE (MGM-13A)," Airmunitions Test, Report No. OOY-TR-64-877, Ogden Air Materiel Area, Hill AFB, Utah, 20 pp., March 1964.

Inspection (Visual and X-Ray) of 5 motors 60 months old. Tests at -30°F and +160°F. X-Ray revealed insignificant propellant defects. One motor considered nonrepresentative leaked at forward end.

Recommends that shelf life be extended from 5 years to 6.5 years, provided continuous vigilance maintained on exudate problem.

C.11 JATOS (Continued)

C.11.49 R.M. Cavett, "Shelf and Service Life Test of Rocket Motors M16E3 for MACE (TM-76)," Report No. 00Y-TR-63-11, Ogden Air Materiel Area, Hill AFB, Utah, 23 pp., March 1963.

Five motors aged 52 months tested at -30°F and +160°F. Ballistic parameters within specified limits. Recommends extending shelf life to 5 years.

C. 12 NIKE SERIES XM30

C. 12. 1 R. Torres, "Static Tests of Two Aged XM30 Rocket Motors," Report No. RT-TM-64-28, Army Missile Command, Redstone Arsenal, Huntsville, Alabama, 27 pp., 5 June 1964. (C)

Static test firing on two Nike Hercules XM30 motors following exposure to desert and tropical aging for 4 and 5 years. Both motors retro fitted with TX-345 pyrogen igniters.

Indicates that motors perform satisfactorily after exposure to widely differing humidities. However, motor burn time exceeds specification. Ignition delay acceptable with the new TX-345 pyrogen igniter. Previous test showed that ignition delay exceeded tests requirements when using the standard XM-69 igniter.

C. 12. 2 R. J. Massant, "Static Tests of Five Aged XM30 Rocket Motors," Report No. RT-TM-63-37, Army Missile Command, Redstone Arsenal, Huntsville, Alabama, 57 pp., 2 May 1963. (C)

Primary attention to changes in ballistics; data on changes in chemical and physical properties of propellant. (TRXE-110C) and effects of storage on both standard and waterproof squibs, pyrogen units, and blast tubes.

Excessive ignition delay—from 0.335 to 0.694 second, no hot spots. Action time exceeded effective burn time by about 4 seconds for all five motors. On round S-20, T_b exceeded specifications of 36 seconds by 1.250 seconds. Separation in Number 209 not detrimental.

Concludes XM30 rocket motor will not function normally after 5 years but will not fail on ignition. Extended storage under desert and tropic conditions affects ignition.

C. 12. 3 Quarterly Report, Report No. ARGMA TR 1D1R-Z, Propulsion Laboratory, Ordnance Missile Laboratories Division, AMC, Redstone Arsenal, Huntsville, Alabama, 79 pp., November 1959. (C)

Reports of Aging Program for Nike-Hercules sustainer motor (XM30).

SPRINT

C. 12. 4 R. F. Culley, "NIKE X-SPRINT Ground Support Equipment Development Studies," AMC-RA-RF-TR-64-2, AMC, Redstone Arsenal, Huntsville, Alabama, 15 February 1964. (S)

C. 12 NIKE SERIES XM30 (Continued)

ZEUS

C. 12. 5 R. P. Ware and R. L. Hollingworth, "Nike Zeus," Monthly Reports C-62-354A, C-63-324A, and C-63-342A, Thiokol Chemical Corporation, Alpha Division, Huntsville, Alabama, 249 pp., January to March 1963. (C)

Propellant properties satisfactory after 20 weeks at 135°F.

Aging studies at elevated temperatures continued on HC polymer liners (TA-H711B) and adhesive (TA-H714B). HC polymer cured with HX740/HX760 mixture. Tensile and peel strengths satisfactory after 6 weeks accelerated aging.

C. 12. 6 W. M. Savelle, "Development of Propulsion System for Nike Zeus Missile," Monthly Report No. C-A-61-193A, April to August 1961, Thiokol Chemical Corporation, Redstone Division, Huntsville, Alabama, 26 September 1961. (C)

After 6 months of storage at 140°F, motor components have shown no detrimental effects from the zinc chromate putty used as a sealer. The aging program is to continue for 1 year.

AJAX

C. [illegible] [illegible]mes V. Beyer and B. M. Storey, "Storage Test on Nike-Ajax [illegible]," AMC-RA RT-TR-63-7, AMC, Redstone Arsenal, Huntsville, [illegible]ama, 21 April - 5 August 1963.

C. 13 PERSHING

C. 13. 1 W. C. Burleson, et al., "Thermal Analysis of a Pershing XB-1 Motor Subjected to a Cold Environment (U)," Report No. RS-TR-62-3, X63-10915, Army Missile Command, Huntsville, Alabama, November 1962. (C)

C. 13. 2 "Pershing Propulsion System Development Program," Monthly Technical Progress Report Nos. C-A-62-216A, C-A-62-227A, C-A-62-241A (File Nos. F4552, F4754, F5070), Thiokol Chemical Corp., Alpha Division, Huntsville, Alabama, p. 53, 21 June - 20 September 1962. (C)

Propellant aging study to determine effects of temperature and humidity on propellant storability.

C. 13. 3 "Pershing Propulsion System Development Program," Monthly Technical Progress Report Nos. C-A-62-157A, C-A-62-172A, C-A-62-188A, C-A-62-202A (File Nos. F3566, F3773, F4040, F4339), 67 pp., 21 February, 20 June 1962. (C)

Aging and surveillance of propellant continued. High temperature and/or humidity causes degradation. Ambient conditions (70^{o}F and 30 percent RH) least affect propellant properties. Very low humidity (77^{o}F and 0 percent RH) caused propellant hardening.

Recommended N_2 atmosphere in bore if seals are adequate to retain the gas. Otherwise, continue using desiccants.

C. 13. 4 "Pershing Propulsion System Development Program," Monthly Technical Progress Report No. C-A-61-263A, 21 July - 20 August 1961, 7 September 1961. (C)

The first full year of the 5-year aging and surveillance program on TP-H8041 propellant was completed. Data indicated increased physical strength and decreased extensibility after elevated temperature storage.

C. 13. 5 "Pershing Propulsion System Development Program," Monthly Technical Progress Report No. C-A-61-174A, 21 March - 20 April 1961, Thiokol Chemical Corp., Redstone Division, Huntsville, Alabama, 4 May 1961. (C)

Propellant aging studies were conducted after 8 months storage at ambient, 140 and 170^{o}F.

C. 13. 6 "Pershing Propulsion System Development Program," Monthly Technical Progress Report No. C-A-61-160A, 21 February - 20 March 1961, Thiokol Chemical Corp., Redstone Division, Huntsville, Alabama, 7 April 1961. (C)

Ignition system exploding bridge wire initiator units were exposed to 95 percent relative humidity and tested at 2 week intervals. Units were satisfactory after a period of 8 weeks. Propellant stored for 7 months at ambient, 140 and 170^{o}F showed continued increases of physical strength and decreases of extensibility at 140 and 170^{o}F.

C. 13 PERSHING (Continued)

C. 13. 7 "Pershing Propulsion System Development Program," Monthly Technical Progress Report No. C-A-61-141A, 21 January - 20 February 1961, Thiokol Chemical Corp., Redstone Division, Huntsville, Alabama, 8 March 1961. (C)

Tests were run to determine effect of high temperature storage on the resistance and dielectric strength of the TX-221-1 initiator body. Various propellant samples are being aged. A study was initiated to determine the effects of various greases, lubricants and hydraulic fluids on the propellant and liner.

C. 13. 8 "Pershing Propulsion System Development Program," Monthly Technical Progress Report No. C-A-60-537A, 21 November - 20 December 1960, 26 pp. and C-A-61-12A, 21 December - 21 January 1961, 31 pp., 10 January 1961. (C)

Aging study to determine effects of 170°F storage on propellant-liner bond strength. Tests indicate good bonds after 10 months. Propellant aged 1 year under various conditions.

C. 13. 9 "Pershing Propulsion System Development Program," Monthly Technical Progress Report No. C-A-60-509A, 21 October - 20 November 1960, Thiokol Chemical Corp., Redstone Division, Huntsville, Alabama, 13 December 1960. (C)

Propellant modifications to improve storage life.

C. 13. 10 "Pershing Propulsion System Development Program," Monthly Technical Progress Report No. C-A-60-471A, Thiokol Chemical Corp., Redstone Division, Huntsville, Alabama, 9 November 1960. (C)

Propellant aging studies are in the third month with no significant changes of mechanical properties being noted.

C. 13. 11 "Pershing Propulsion System Development Program," Monthly Technical Progress Report No. C-A-60-407A, 21 July - 20 August 1960, Thiokol Chemical Corp., Redstone Division, Huntsville, Alabama, 8 September 1960. (C)

Accelerated aging program initiated to complete the characterization of the P-8 liner. Environmental testing of impulse control mechanisms and exploding bridge wire sectors completed. Short and long term propellant aging studies being conducted.

C. 13. 12 "Pershing Propulsion System Development Program," Report No. C-A-60-221A, 21 February - 20 March 1960, Thiokol Chemical Corp., Redstone Arsenal, Huntsville, Alabama, 6 April 1960. (C)

Propellant aging tests were run for 16 weeks. A general increase in elastic modulus and a decrease in ultimate elongation was noted as storage temperatures increased.

C. 14 REGULUS/PRODUCER

C. 14. 1 V. E. Hart, "Nondestructive Testing of JATO Unit 2. 2KS-33, 000 X105 HI," Report No. QEI/NPP 59-7, U. S. Naval Propellant Plant, Indian Head, Maryland, 20 November 1959. (C)

Several misfires of the booster units for Regulus I guided missile (X105 HI, 2. 2KS-33, 000) were studied by nondestructive investigation of 20 units. Silicone grease was found on surface layer of grain, and felt pads supporting grain lost their resilience on aging. Also, chemical changes were noted on surface of propellant.

C. 14. 2 L. J. Bornstein, et al., "Development of 3KS-33, 000 Solid-Propellant Booster Rocket (Regulus I)," Reports L2201-1 through -8 (Monthly), January - October 1956, (Contracts NOrd 16588), Aerojet-General Corp., November 1956. (C)

Reports 1-4, results of 11 full scale firings made at conditioning temperatures -50 to +150°F, case-bonding problems.

Reports 5-8, 11 linerless engines were temperature cycled and placed in storage, 9 exhibited case bond failure due to rust on propellant to metal interface due to condensation brought on by temperature cycling. Corrective measures taken.

C. 14. 3 R. H. Kempter, "Use of Acrylate-Fuel Propellant for 3KS-33, 000 Booster," Report No. 1064 (Special), Aerojet-General Corp., 43 pp., 4 tables, 26 figures, 28 February 1956. (C)

Temperature cycling tests on liner materials such as clear sodium silicate, B. F. Goodrich Co.'s Pyrolock, and combinations of aluminum oxide and sodium silicate.

C. 14. 4 A. R. Apodaca, et al., "Design and Development of 31KS-30, 000 Booster," Report No. 1029 (Final), Aerojet-General Corp., 82 pp., 19 tables, 138 figures, 2 appendices, 1 December 1955. (C)

Accelerated aging tests at 210°F for 3 months on Acrylate propellants showed no change in physical properties.

C. 14. 5 "Development of Composite Propellant Booster Unit," Report No. 726-1-58 (Final), 1 May 1956 - 12 December 1957, Astrodyne, Inc., McGregor, Texas, 217 pp., 105 figures, 40 tables, numerous appendices. (C)

Reports storage of "Producers" for 1 year at 170°F.

C. 15 SERGEANT

C. 15. 1 T. C. Sushinski and D. W. Rankin, "Report of Firing Test of Sergeant Shelf and Service Life Round 2 Interim Report," Report WSMR-AMTED Sergeant 66-4, AD366-863L, August 1962 - December 1964, Army Missile Test and Evaluation Directorate, White Sands, New Mexico, October 1965.

C. 15. 2 "Solid Propellant and Igniter Development," Quarterly Report No. 3M7N22, 1 April - 30 June 1957, Redstone Arsenal, Ordnance Missile Laboratories, 84 pp., 49 figures, 19 tables, 1 July 1957. (C)

Tests of samples taken from a Sergeant motor aged for 35 days at 140°F indicate that comparisons can be made between aging of small laboratory propellant samples and the aging of propellants in full scale motors.

Moisture resistance of squib materials studied.

C. 15. 3 "Development of Sergeant Rocket Motor," PR Report Nos. 1-56, 10-56, 21-56 and 33-56 (Quarterly), October 1955 - September 1956, Thiokol Chemical Corp., Redstone Division, Huntsville, Alabama, September 1956. (C)

Difficulties in the heat treatment of Sergeant cases after addition of numerous flight attachment fittings (PR 10-56).

One motor case was hydro-tested; it burst at 1200 psi (PR 10-56, 21-56 and 33-56).

C. 16 SIDEWINDER

C. 16. 1 G. S. Merry, "Sidewinder 1A Propulsion Unit Type - Life Program," Report No. NPP-TMR-230, December 1959 - August 1965, U. S. Naval Propellant Plant, Indian Head, Maryland, 55 pp., 6 December 1965. (C)

C. 16. 2 R. E. Boudreaux, "General Surveillance of Sidewinder 1A Rocket Motors, Mark 15 and 17," Report No. QE/NPP 63-19, U. S. Naval Propellant Plant, Indian Head, Maryland, 28 pp., 29 February 1964. (C)

Evaluated by exterior, interior, X-ray and dimensional inspection, ballistic, physical and chemical tests. Concluded that Mark 15 and 17 are acceptable and recommends extending service life to 9 years.

C. 16. 3 "Report of Surveillance Testing of SGU Series 10 Fleet Returns Over Two Years Old," Report No. TNR 192 (File No. F2665), U. S. Naval Propellant Plant, Indian Head, Maryland, 57 pp., 1 May 1961. (C)

Sidewinder Gas Generators Series 10—several lots tested after 22 to 42 months storage in fleet. Increase in P_c max at 130°F noted. Visual examination indicated no NG migration into the inhibitor.

Recommended shelf life extended but upper temperature limit reduced from 100°F to 90°F. Also develop new inhibitor.

C. 16. 4 "Research and Development Department, U. S. Naval Powder Factory, Technical Progress," Second Quarter Fiscal 1958, Naval Powder Factory, Indian Head, Maryland, 166 pp, numerous figures and tables. (C)

Aging of 72 Sidewinder motors at 130°F for 45 days.

C. 17 SPARROW/SHRIKE

C.17.1 P. F. Nicol, "Logistics Plan for Guided Missile AGM-45A (SHRIKE), Revision 1," Report No. NOTS-TP-3972, NAVWEPS 8520, Revision, U.S. Naval Ordnance Test Station, China Lake, California, October 1965. (C)

C.17.2 "Structural Analyses of the SPARROW/SHRIKE Propulsion Systems" Report No. 1964, AD366457, Emerson Electric Co., Electronics and Space Division, St. Louis, Missouri, 30 September 1965.

C.17.3 A. Pataland, "General Surveillance of SPARROW III AIM 7-C and AIM 7-D Electrical Power Unit (EPU) Gas Generator," Report No. QAS/NPP 65-24, U.S. Naval Propellant Plant, Indian Head, Maryland, 31 pp., 12 July 1965. (C)

SPARROW III AIM 7-C and AIM 7-D air-to-air missiles use on-board EPU's. Both 7-C and 7-D use gas generators (double base) to power turbo generator. Program included:

23 Fleet Returns	7-C EPU Grains
21 Zero Time	
43 Fleet Return	7-D EPU Grains

Grains performed successfully. No evidence of deterioration. Recommend 8 year shelf life.

C.17.4 "Explosive Component Surveillance Plan SPARROW III A/B Missile (AIM 7-D/E)," Report No. 00YITM-64-T-1S, Ogden Air Materiel Area, Hill Air Force Base, Utah, 13 pp., April 1964. (U)

Plan designed to provide surveillance, inspection and testing of SPARROW III A/B explosive components including Mark 38 Model 0 Rocket Motor, Mark 265 Model 0 Igniter and Mark 5 Model 0 S/A Device.

Objective to establish and confirm manufacturer's estimate of shelf life and extend to the ultimate (where practicable) with respect to environment envelope of SPARROW III A/B Missile, to develop destructive and nondestructive inspection techniques and establish reliability and serviceability criteria.

C.17.5 B. F. Hinderer, "Development of the Mark 38 Model 0 Rocket Motor for the SPARROW III 6b Missile," CPIA Publication No. 18A, Bulletin of the Interagency Solid Propulsion Meeting, vol. IV. Addendum, Rocketdyne, a Division of NAA, Inc., McGregor, Texas, CPIA, Silver Spring, Maryland, pp. 577-596, July 1963. (C)

Discusses endurance vibration time-to-failure of a free standing propellant grain.

C.17.6 V. E. Hart, "Quality Surveillance of SPARROW III Guided Missile Sustainers Mark 6 (1.8KS-7800)," Report No. QE/NPP 62-17, U.S. Naval Propellant Plant, Indian Head, Maryland, 15 pp., 1 February 1963. (C)

C. 17 SPARROW/SHRIKE (Continued)

QE tests on 21 motors. All ballistic parameters were within specification.

Nozzle weather seals were incompletely bonded. Recommended redesign of weather seal but no limit on shelf life.

C. 17.7 T. R. Kornreich, "Quality Evaluation of Fleet - Returned 1.8KS-7800 X113 C7 Rocket Motors for Sparrow," QE/NPP 59-2 U. S. Naval Propellant Plant, Indian Head, Maryland, 22 May 1959. (C)

Procedures for determining serviceability of fleet stocks established and described.

C. 17.8 C. G. Campbell, "Development of a 2KS-8600 Rocket Engine (Sparrow)," Reports No. L2254-13 through -16, Aerojet-General Corp., Sacramento, California, 28 March 1958. (C)

Reports data on accelerated aging of Sparrow motors at 170°F, also temperature cycling between -75 and 170°F.

C. 17.9 L. W. Kesting, "Qualification Test of the EI Sparrow Rocket Motor," NARTS Report No. 92 (TED-ARTS-SI-5209), U. S. Naval Air Rocket Test Station, Lake Denmark, New York, 37 pp., 4 tables, 16 figures, August 1956. (C)

Fifty-one X113 EI Sparrow 1.8KS-7800 rocket motors developed and produced by Aerojet-General Corp. were given qualification tests.

Defective igniter ports and throat seals were noted.

C. 17.10 "Explosive Component Surveillance Plan AGM 45A (SHRIKE) Missile," Report No. 00YITM-64-T-S, Ogden Air Materal Area, Hill Air Force Base, Utah, 11 pp.

Plan to confirm manufacturer's shelf life and extend the ultimate useful life (when practical). Plans for field and depot level inspection and testing.

C. 18 SUBROC

C. 18. 1 M. H. Bart, et al., "Development of the Subroc Rocket Engine," Report No. E51-60, Thiokol Chemical Corp., Elkton Division, Elkton, Maryland, January-February 1960. (C)

Studies conducted to determine the effect of 250°F aging on the physical properties of PR-10L mastic insulation indicate that shear strength is unaffected by aging.

C. 18. 2 M. H. Bart, et al., "Development of Subroc Rocket Engine," Report No. E24-60, Thiokol Chemical Corp., Elkton Division, Elkton, Maryland, December 1959 - January 1960. (C)

Surveillance of low and high temperature aging properties was continued. After 2 months at 130°F no significant difference in ballistic properties of propellant was noted.

C. 18. 3 M. H. Bart, et al., "Development of the Subroc Rocket Engine," Report No. E141-29, Thiokol Chemical Corp., Elkton Division, Elkton, Maryland, April-May 1959. (C)

Tensile specimens of DA-103A propellant were tested for physical properties at 10°F after aging at that temperature.

C. 18. 4 M. H. Bart, et al., "Development of the Subroc Rocket Engine," Report No. E97-59, Thiokol Chemical Corp. Elkton Division, Elkton, Maryland, March 1959. (C)

Propellant accelerated aging program has been extended to 16 weeks. After 11 weeks stress, strain, modulus and hardness remain relatively unchanged at both ambient and 140°F.

C. 18. 5 M. H. Bart, et al., "Development of the Subroc Rocket Engine," Report No. E32-59, Thiokol Chemical Corp., Elkton Division, Elkton, Maryland, December-January 1959. (C)

Physical property data for propellants DA-103 and DA-103A after 6 weeks of ambient storage indicated that stress, strain and modulus were unchanged while hardness increased slightly.

C. 18. 6 M. H. Bart, et al., "Development of the Subroc Rocket Engine," Report No. E241-58, Thiokol Chemical Corp., Elkton Division, Elkton, Maryland, November-December 1958. (C)

C. 19 TALOS

C. 19. 1 A. E. Kartman, "Talos Logistics Environmental Study, (U) Final Report," Report No. BxM-5893, AD363821L, Bendix Mishawaka, 28 May 1965. (C)

C. 19. 2 D. E. Madsen, "Surveillance of Fleet Returned Talos Boosters Mk 11 Mod 1, Mk 11 Mod 2: Talos Booster and Igniter Mk 177 Mod 1," Report No. QAS/NPP 64-3, U.S. Naval Propellant Plant, Indian Head, Maryland, 31 pp., 2 May 1964. (C)

First surveillance testing of Fleet-Returns. The Mod 1 booster is obsolete.

No critical defects reflecting age-induced faults detected. Grains sound after 3 years. NG migration into inhibitor. Black powder in igniter is chemically stable. Ballistic performance degraded-particularly at -10°F. OK at 100°F. Igniter ballistic performance at 4.5 years meets model specifications.

Recommendations: 6 years service life for the Mod 2 motor with provision that I_t degradation does not affect missile performance. Seven year life for Mk 177 Mod 1 igniter. Depots urged to use care with O-Rings when installing igniter.

C. 19. 3 "Mark 11 Mod 2 Talos Booster Type-Life Program 1.0 Year Summary Report," Report No. 8821/2, U.S. Naval Propellant Plant, Indian Head, Maryland, 26 pp., 26 July 1963. (C)

Predict serviceability and provide information for design of future units. Presents type-life ballistic, chemical and physical data for 0.5 and 1.0 year tests and ancillary data on three non-type-life firings.

C. 19. 4 B. Barisa, "Type-Life Program for the Talos Booster Mk 11 Mod 1, Results through the 1.0 Year Test," Technical Memo Report No. 197, U.S. Naval Propellant Plant, Indian Head, Maryland, 15 January 1962. (C)

Grains loaded in motors in controlled-temperature storage, moderate accelerated aging. After two 6-month cycles equivalent age of 3 years assumed. Most significant effect was loss of I_t in low temperature firings.

Minor defects listed as follows:

1) Nitrogen bottle weight
2) Clamp ring hammer condition
3) Effort required for the electrical arming/disarming.

C. 19. 5 "Status of Development Projects," ABL/QPR 16, 15 July - 15 October 1959, Allegany Ballistics Laboratory, Cumberland, Maryland, 15 November 1959. (C)

Six Talos boosters stored for over 2 years were fired.

C. 20 TARTAR

C. 20. 1 A. J. Roberts, "Increased Scope Program Improved Tartar Motors," Report No. 0292-06F (Final), 11 April 1961 - 30 June 1963, Aerojet-General Corp., Sacramento, California, 5 September 1963. (C)

Five of six aging-test motors showed significant propellant degradation during environmental testing. Not fired, inspected by X-ray.

The 12 month aging tests showed defects in both booster and sustainer propellants that resulted in cracking of booster grain. Storage/firing temperature limits reduced-interim measure.

C. 20. 2 T. A. Thrasher, et al., "Development of a Dual-Thrust Rocket Motor for the Tartar Missile (U)," Report No. 0118-01Q-9, Ninth Progress Report 16 July - 15 October 1960, Aerojet-General Corp., Sacramento, California, 28 February 1961. (C)

Three Tartar motors aged at +130°F for 27 weeks were fired successfully.

C. 20. 3 R. G. Coppe, "Development of a Dual-Thrust Rocket Motor for the Tartar Missile," Report No. 0118-01Q-8, 16 April - 15 July 1960, Aerojet-General Corp., Sacramento, California, 31 August 1960. (C)

At 27 weeks in the accelerated aging program, three motors stored at +130°F have not shown liner-chamber separation and only one motor out of three at -30°F has developed bond separation.

C. 20. 4 J. C. Farber, et. al., "Dual-Thrust Unit for Tartar," MPR Nos. 52, 56, 58, 60 (16640), Allegany Ballistics Laboratory, Cumberland, Maryland, October 1956. (C)

MPR 56 A grain-holdback mechanism consisting of six springs welded to two annular rings was fabricated and tested. The grain-holdback did not withstand the static test.

C. 21 TERRIER

C. 21. 1 D. Sinacore, "Correlation of Mechanical Properties, Grain Cracking, and Internal Ballistics Data for the Terrier Sustainer Propellant Grain, MK 52 Mod 0," Report No. QAS/NPP-65-29, AD366880, U.S. Naval Propellant Plant, Quality Assurance Department, Indian Head, Maryland, 5 November 1965. (C)

C. 21. 2 D. Sinacore, Jr., "Quality Surveillance of the Terrier Sustainer Mk 7 Mod 0," Report No. QAS/NPP 64-12 Final, U.S. Naval Propellant Plant, Indian Head, Maryland, 43 pp., 30 June 1965. (C)

Program to evaluate serviceability of Mk 7 Mod 0-45 motors from fleet returns tested. Approximately 4 years old. External, internal inspection, grain X-ray, firing, mechanical properties testing and chemical analysis.

Cracks in grain appear to be inherent in grain design. Development/propagation of cracks depends on support of slot spacers, age and firing temperature; ballistic performance and grain stability not limiting factors; physical integrity of grain is limiting factor.

C. 21. 3 I. E. Kilmon, "Terrier Booster, 2. 0 Year Withdrawl," Type-Life Report 65-1, U.S. Naval Propellant Plant, Indian Head, Maryland, 25 February 1965. (C)

Thirty grains from Naval Propellant Plant Lot 16 loaded in motors and put in controlled temperature storage. After four 6-month temperature cycles (2 years), equivalent age estimated at 4 years.

Most significant aging effects: (1) loss in I_t, (2) increase in propellant brittleness and (3) more propellant breakup during burning.

The 2. 0 year withdrawal showed: (1) strand r_b of CAP and AHH propellant stabilizing, (2) I_t still below lower specification limit, (3) NG migrating across web into inhibitor and (4) propellant grain still has high degree of stability.

Recommends 4 year safe and service life for Mk 2 Mod 0.

C. 21. 4 D. Madsen, "General Surveillance of the Seven Year Old BW-O Terrier Sustainer Mk 2 Mod 0," Report No. QE/NPP 63-2, U.S. Naval Propellant Plant, Indian Head, Maryland, 26 pp., 5 April 1963.

Evaluation of serviceability of Mk 2 Mod 0 Terrier Sustainer with Propellant Grain Mk 34 Mod 0 and Igniter Mk 155 Mod 1. Used six static firings, chemical/physical analysis of two grains, chemical analyses of two inhibitor samples and inspection of components of five motors.

Eighty percent of Mk 1 Mod 0 immobilizers developed damping fluid leaks at 7 years storage.

Recommend extend life to 10 years exclusive of the igniters.

C. 21 TERRIER (Continued)

C. 21. 5 D. E. Madsen and G. A. Kalvin, "General Surveillance of the BW-O Terrier Booster at Grain Age 7.0 Years," Report QE/NPP 62-51, U.S. Naval Propellant Plant, Indian Head, Maryland, 35 pp., 8 February 1963. (C)

BW-O Terrier Booster Mk 3 Mods 1 and 2, Booster Grain Mk 33 Mod 0 and Igniter Mk 154 Mod 3 evaluated for use at 7 years. Nine static firings, one motor dissection. A 2 to 3 percent decrease in I_t.

Proposes test program for Igniter Mk 154 Mod 3. Recommends extending motor life to 8 years.

C. 21. 6 "Terrier Booster and Sustainer Motor Quality Evaluation," Report No. 3930/1, U.S. Naval Propellant Plant, Indian Head, Maryland, 20 January 1960. (C)

Results of surveillance tests conducted on 21 missile boosters Mk 2 Mod 3, Mk 3 Mods 1 and 2 and five missile sustainers Mk 2 Mod 0 which are the propulsion system for the Terrier BW-O missile. Recommends that storage life be extended 5 to 7 years.

C. 21. 7 T.R. Kornreich, "Quality Evaluation of Terrier Missile Propulsion Systems," Report QE/NPP 58-13, U.S. Naval Propellant Plant, Indian Head, Maryland, 30 March 1959. (C)

Recommends that the service life of the Mk 33 Mod 0 and the Mk 34 Mod 0 propellant grains should be extended to 5 years.

C. 21. 8 A. A. Bacher and T. R. Kornreich, "Quality Evaluation of 'Over-Aged' Terrier Missile Sustainers Mk 1 Mod 1 and Mk 1 Mod 3," Report QE/NPP 56-11, U.S. Naval Propellant Plant, Indian Head, Maryland, 14 October 1958. (C)

Service life of propellant and igniters evaluated. Increased nitroglycerine content of the inhibitor. A significant difference (6-9 months) between date of grain manufacture and loading date gave a false impression of actual age.

C. 21. 9 J.H. Spalding, Jr., "Quality Surveillance of Boosters and Sustainers from Fleet-Returned Terrier Missiles," Report QE/NPF 58-5 (Quality Evaluation Lab Report), Naval Powder Factory, 10 pp, numerous figures and tables, 14 April 1958. (C)

Five units each of Terrier Booster Mk 3 Mod 1 and 2 and Sustainers Mk 2 Mod 0 returned from the U.S.S. Wrangell were disassembled and inspected to determine the effect of service use upon the apparent quality level.

C. 21. 10 "Handling and Operating Instructions for Missile Booster Mk 2 Mods 1-3, Mk 3 Mods 0-2," Report ABL/M-45, Allegany Ballistics Laboratory, 25 pp., 16 figures, April 1956. (C)

Brief description of the Terrier Booster Mk 2 and Mk 3 and the instructions for handling, storing, testing and operating.

C. 21 TERRIER (Continued)

C. 21. 11 "Terrier Booster and Sustainer Typ ife Program 3. 0 and 3. 5 Year Ballistic Test Report," R rt No. 8821/1, U.S. Naval Propellant Plant, Indian Head, Maryland, 79 pp. (C)

Summary of ballistic, chemical and physical tests.

C. 21. 12 W. J. Adams and C. E. Brookiy, "Four-Year Storage Evaluation of Cast Double Base Rockets," ABL/MPR 59, Allegany Ballistics Laboratory, Cumberland, Maryland, 1 September 1956. (C)

An X216 unit stored for 4 years at ambient temperature was disassembled for inspection before firing. The overall condition of the unit was good; therefore the unit was reassembled and fired. Ballistic performance was satisfactory.

C. 22 MISCELLANEOUS MOTORS

ALTAIR/ANTARES X248/X254

C. 22. 1 M. B. Robin, "Age Life Study of X248 and X254 Motors and Firing of X254 Motor," S/N F-25, Report No. SSD-TDR-64-56, AD430279, X65-15117, Hercules Powder Company, Cumberland, Maryland, February 1964.

Fired S/NF-25 after 26 month storage. Extended service life of 18 to 36 months on the X248 and to 24 months on the X254.

ATHENA BE-3-A2

C. 22. 2 M. A. Nelius, "An Investigation of the Effects of Storage Time on the Performance of a Hercules Powder Company BE-3-A2 Rocket Motor (U)," Report No. AEDC-TDR-64-190, AD-353414, X65-10267, Arnold Engineering Development Center, Tennessee, September 1964. (C)

One 30-month solid-propellant rocket motor was tested at a pressure altitude of 108,000 feet. The specific impulse compared within 0.25 percent of the average of similar motors tested at AEDC. The storage period had no apparent effect on either motor performance or structural integrity.

C. 22. 3 C. F. Nokes, Jr., "Altitude Testing of Hercules Powder Company BE-3 Rocket Motor (Phase III Surveillance Round Firing)(U)," Report No. AEDC-TDR-62-222, X63-10899, AD-333984, Arnold Engineering Development Center, Tennessee, January 1963. (C)

Altitude tests of 1-year BE-3 motors.

BULLPUP SUSTAINER

C. 22. 4 H. Solomon and D. Madsen, "Fleet Return Surveillance of Bullpup Sustainers Mk 8 Mod 1," Report No. QE/NPP 62-5, U.S. Naval Propellant Plant, Indian Head, Maryland, 27 pp., 22 August 1962. (C)

Bullpup sustainer Mk 8 Mod 1, Grain Mk 51 Mod 0 and igniter Mk 178 Mod 1 evaluated. Sustainer 33-months old. Static firings, physical and chemical analysis of two grains and two igniter charges and data from six igniter chamber firings. Recommended to extend service life to 5 years.

CASTOR XM33E2

C. 22. 5 R. J. Massarotti and F. D. Peace, "Static Test of One XM33E2 Rocket Motor Test No. 3," Report No. RT-TM-62-30, Army Ordnance Missile Command, Redstone Arsenal, Huntsville, Alabama, 18 pp., 29 July 1962. (C)

Motor fired to test effects of 2 years ambient aging at Redstone. Motor functioned normally.

C. 22 MISCELLANEOUS MOTORS (Continued)

DART XM-23

C. 22. 6 R. E. Ahern, E. O. Graham and R. L. Schoen, "Development of the Dart Missile Propulsion System for Redstone Arsenal," QPR No. 1, Grand Central Rocket Co., 7 pp., 3 tables, 4 figures, 29 February 1956. (C)

Environmental testing of the liner system in the XM-23 Dart anti-tank missile indicated the liner system did not cycle satisfactorily. Separation was noted when the grains were cycled between -40 and 140°F. Firings of RX-2 grains aged for 4 or 6 months were satisfactory. Drop tests were also conducted on the XM-23 motors.

DIMPLE MOTOR M-4

C. 22. 7 C. R. McGraw, "Shelf and Service Life Test on M-4 Dimple Motor, P/N 147740, AIM-4A/4C/26A/26B," Report No. OOY-TR-64-886, Ogden Air Materiel Area, Hill AFB, March 1964.

Program to extend shelf life from 5 to 7 years on M-4 Dimple motors when used as component on AIM-4A/4C/26A/26B frequency converter. When used on various fuzes the M-4 has 7-year life; but on the frequency converter, found physical degradation, duds, and marginal functions coupled with instability of bridgewire resistance (attributed to age).

Recommends the M-4 Dimple motor life, when used on the frequency converter, should not be extended and all units on frequency converter be replaced.

GIMLET

C. 22. 8 R. L. Eidemiller, et al., "Use of Fractional Replication Designs in Exploratory Rocket Development Investigations," Report No. NOTS 1941 NAVORD Report 5844, U. S. Naval Ordnance Test Station, China Lake, California 24 pp., 2 figures, numerous appendices, 24 February 1958. (C)

Study on the 2. 0-inch Gimlet rocket motor to determine the cause of the tube bulging and obturation failure.

QUAIL GAM-72

C. 22. 9 "Service Life Test of Cartridge Shackle Ejector for the GAM-72 Missile," Report No. AD 407548, Ogden Air Materiel Area, Hill AFB, Utah.

C. 22 MISCELLANEOUS MOTORS (Continued)

REDEYE

C. 22. 10 "Redeye Research and Development Program," Monthly Reports CR-592-623-016, -017, -018, Contract DA-04-495-AMC-315, General Dynamics, Pomona, California, February-April 1965.

Analytical study for predicting moisture buildup in the REDEYE Launch Tube during 2-year storage period.

C. 22. 11 "Development and Production of a Solid Propellant Rocket Motor for the Redeye Missile," Monthly Progress Report Nos. 16 through 21, December 1960 through May 1961, Atlantic Research Corp., Alexandria, Virginia, 28 June 1961. (C)

Physical property tests of grains after 9 months at -60, 70, and 140°F and static firings after 11 months at temperature were satisfactory.

RETROROCKET DM-18

C. 22. 12 L. M. Singer, "Surveillance and Reliability Tests on DM-18 Retrorocket Motors (Mark 8A1, 1.5KS-860)," Report No. OOY-TR-63-3, Ogden Air Materiel Area, Hill AFB, Utah, 47 pp., February 1963. (C)

Tested 15 DM-18 retrorocket motor grains that were 45 months old. Inspected visually and radiographically. Igniters and rocket motors conditioned and fired at -65, +70 and +165°F. Successfully analyzed F, P_c, T_d, burn time and I_t.

Recommended that 45 month old grains have shelf life extended to 57 months.

SCOUT

C. 22. 13 C. M. Frey, "Fourth Stage SCOUT Rocket Motor Program, Semi-Monthly Report, 16-31 December 1964," UTC-2100-SMPR15, United Technology Center, Sunnyvale, California, 11 January 1965.

Failures of Motor S/N 20004 because of a gas leak in the rubber insulator and polar fitting.

SKYBOLT

C. 22. 14 "Explosive Component Surveillance Plan GAM 87A," Report No. OOYIT-SP-62-1, GAM 87A (File No. F4162), Ogden Air Materiel Area, Hill Air Force Base, Utah, 16 pp., June 1962.

Program plan for surveillance, inspection and testing of Skybolt explosive components.

C. 22 MISCELLANEOUS MOTORS (Continued)

SNARK, X226A3 ROCKET MOTOR MK 9 MOD 0

C. 22. 15 P. M. Gilmore and D. F. Woods, "Explosive Component Surveillance Program," Report No. SM-62A, Ogden Air Materiel Area, Hill Air Force Base, Utah, July 1960. (U)

A surveillance program is outlined for the SM-62A Weapon System, including the Mk 9 Mod 0 (X226A3) rocket motor and the Mk 176 Mod 0 igniter.

TORPEDO MK 1 MOD 0

C. 22. 16 D. R. Cruise, E. L. Moon and C. A. Taylor, "Surveillance Study of the Torpedo Booster Motor Mk 1 Mod 0 of the Rocket-Thrown Torpedo," NOTS 2075 NAVORD Report No. 6387, U. S. Naval Test Station, China Lake, California, 33 pp., 4 tables, 5 September 1958. (C)

Fifty Torpedo booster motors Mk 1 Mod 0 of the Rocket-Thrown Torpedo (RAT) were used in accelerated aging tests to predict performance changes during the useful life of the motor.

WOLFHOUND AND FOXHOUND

C. 22. 17 "Research and Development Work on Cast Double-Base Propellant Rockets (Report for Month of December 1958)," Imperial Chemical Industries Ltd. (Confidential/Discrete)

Storage of Wolfhound and Foxhound motors at 125°F for 6 months. Storage of glass fiber/synthetic resin motor cases was investigated.

ZUNI

C. 22. 18 E. L. Moon, "Development of Accelerated-Aging Techniques in Surveillance of the Zuni Grain," NOTS 1749 NAVORD 5557, U. S. Naval Ordnance Test Station, China Lake, California, 29 pp., 5 tables, 13 figures, 1 appendix, 30 July 1957. (C)

A method was developed for estimating storage times at elevated temperatures to produce a predetermined level of plasticizer migration in the peripheral inhibitor of the Zuni grain.

C. 23 NPP SURVEILLANCE/TYPE-LIFE PROGRAMS OF NAVY ROCKET MOTORS

C. 23. 1 "Type-Life Programs (U), Technical Report No. 158, NAVWEPS Report No. 8690, U.S. Naval Propellant Plant, Indian Head, Maryland, 22 pp., July-September 1964. (C)

Ballistic, mechanical, and chemical/physical tests were conducted for the following:

Mk 1 Mod 0 ASROC
Mk 25 Mod 1 5NS-4500 JATO
Mk 32 Mod 0 (HASP/FLAME)
Mk 46 Torpedo Gas Generator (Mk 8 Mod 0)
Mk 1 Mod 0 Rocket Catapult Ejection Seat
Mk 39 Mod 0 Shrike (special storage program)
Mk 6 Mod 0 Sidewinder 1-C (gas generator)
Mk 27 Mod 0 Tartar (improved)
Mk 2 Mod 1 and Mk 2 Mod 2 (Tartar/Terrier gas generator)
Mk 3 Mod 1 and Mk 3 Mod 2 (Tartar/Terrier gas generator)
Terne III
Mk 9 Mod 0 and Mk 10 Mod 0 Terrier Gas Generator
Mk 12 Mod 0 Terrier Booster
Mk 16 Mod 1 ZUNI
Mk 16 Mod 2 Modified ZUNI

C. 23. 2 "Type-Life Programs (U)," NAVWEPS Report No. 8576, X65-10057, 30 March - June 1964, U.S. Naval Propellant Plant, Indian Head, Maryland, 6 July 1964. (C)

C. 23. 3 "Type-Life Programs," Technical Report No. 152, NAVWEPS Report No. 8576, 6 July 1964, U.S. Naval Propellant Plant, Indian Head, Maryland, 18 pp., March-June 1964. (C)

For units tested see Reference C. 60. 1.

C. 23. 4 "Report on Type-Life Program," Technical Report No. 146, NAVWEPS Report No. 8570, 8 May 1964, U.S. Naval Propellant Plant, Indian Head, Maryland, 23 pp., December 1963 - February 1964. (C)

For units tested see Reference C. 60. 1.

C. 23. 5 "Type-Life Programs," Technical Report No. 143, NAVWEPS Report No. 8567, 31 March 1964, U.S. Naval Propellant Plant, Indian Head, Maryland, October-December 1963.

Type-Life Program conducted to "provide reliability information" for practically all Navy solid propellant motors and auxiliary power devices. Program usually runs 3 to 5 years with withdrawl of motors (from representative lots) at 6 month intervals. For units tested see Reference C. 23. 1.

C. 23 NPP (Continued)

C. 23. 6 "Type-Life Programs," Technical Report No. 138, NAVWEPS Report No. 8456, 25 November 1963, U.S. Naval Propellant Plant, Indian Head, Maryland, 16 pp., July-September 1962. (C)

Progress report on Type-Life Programs at NPP.

C. 23. 7 "Technical Progress Report on Type-Life Programs," Quality Technical Program Report, U.S. Naval Propellant Plant, Indian Head, Maryland, 22 pp., April-June 1962. (C)

For units tested see Reference C. 23. 1.

C. 23. 8 F. J. Worcester, "Type-Life Programs," Technical Progress Report, 30 June 1962, U.S. Naval Propellant Plant, Indian Head, Maryland, 100 pp., January-March 1962.

ASROC	0. 5 year stored at 120°F exudate. Firings normal.
Sidewinder 1C Gas Generator	Five units tested. Igniter seals leaked. Hot age motors high P_c. One igniter with open circuit.
Talos Booster Mk 11 Mod 2 (X-251)	Degradation of I_t. Original S/A not used.
Tarter/Terrier Gas Generator (Mk 2 and 3)	Ignition delay on Mk 2 far above specification.

For other units tested see Reference C. 23. 1.

C. 23. 9 "Type-Life Programs," Technical Program Report (File No. F2678), U.S. Naval Propellant Plant, Indian Head, Maryland, 60 pp., July-September 1961. (C)

Sidewinder 1A Propulsion System	1. 5 years at 120°F and -65°F grain low I_t. Plasticizer on grain perforation. Stearic acid present, may inhibit ignition.
Sidewinder 1A and 1C Gas Generator	Temperature shock range reduced from -30 to +165°F to -30 to +130°F. Noted bulging of igniter closure disc; gassing.
Talos Booster Mk 11 Mod 0 (X-239)	Visual and ballistic tests indicate igniters OK—recommend extend life from 3 to 4 years. Found ARP propellant incompatible with Pyrolock insulation.
Basic Tartar	Extensive unbond in all motors at NPP. Fire only at 80°F.

C. 23 NPP (Continued)

Terrier	3 to 5 years. It decreases at -10 and 130°F A Mk 3 Mod 1 igniter—3 years at 120°F—open circuits on both sides of ignition. Insulation on leads severely cracked. Brown exudate on igniter exposed to propellant. Found no CO_2, ethyl ether or H_2O. Pyrolock insulation unbonded. Second booster fired successfully at 70°F.
Weapon Alpha	No significant change in ballistic performance 2.5 to 3.0 years, but end breakup problem returned.
Zuni	Motors 1.0 year at 120°F. No visual defects in grains. Increase in P_c max and reduction in t_a at -65 and +165°F. One motor was scorched at forward motor tube—attributed to ignition flame confinement.

C. 23. 10 "Type-Life Programs," Technical Progress Report, U.S. Naval Propellant Plant, Indian Head, Maryland, 46 pp., October-December 1961. (C)

Sidewinder 1A Gas Generator	0.5 year storage. Change in P_c max at tailoff.
Sidewinder 1A Propulsion Unit	20 rounds 1.5 years storage tested. Six motors at 2.0 years.
Talos Booster Mk 11 Mod 1 (X-239)	Pyrolock insulation restricted from use in new design, apparent incompatibility with propellant.
Talos Booster Mk 11 Mod 2 (X-251)	Motor loaded in 1960 returned from fleet. Good condition, inhibitor delaminated from propellant.
Tartar/Terrier Gas Generator (Mk 2 and 3)	Firings: gas leak between generator and exit pipe, attributed to burnout of rubber gasket.
Terrier	5 year motors fired; O-ring leaks; Mk 154 Mod 3 igniters showed significant loss in N.G.
Weapon Alpha	3 year 120°F motors: motor safe for 7 years but igniter service life not known, 1-year motors.

C. 23 NPP (Continued)

C. 23. 11 "Type-Life Programs," Technical Program Report (File No. F2678), U.S. Naval Propellant Plant, Indian Head, Maryland, 60 pp., July-September 1961. (C)

Sidewinder 1A Propulsion System	1.5 years at 120 and -65°F, grain low I_t. Plasticizer on grain perforation. Stearic acid present may inhibit ignition.
Sidewinder 1A and 1C Gas Generator	Temperature shock range reduced from -30 to +165°F to -30 to +130°F. Noted bulging of igniter closure disc gassing.
Talos Booster Mk 11 Mod 0 (X-239)	Visual and ballistic tests indicate igniters OK—recommend extend life from 3 to 4 years. Found ARP propellant incompatible with Pyrolock insulation.
Basic Tartar	Extensive unbond in all motors at NPP. Fire only at 80°F.
Terrier	3 to 5 years. I_t decreases at -10 and 130°F A Mk 3 Mod 1 igniter—3 years at 120°F—open circuits on both sides of ignition insulation on leads severely cracked. Brown exudate on igniter exposed to propellant. Found no CO_2, ethyl ether or H_2O. Pyrolock insulation unbonded. Second booster fired successfully at 70°F.
Weapon Alpha	No significant change in ballistic performance 2.5 to 3.0 years, but end breakup problem returned.
Zuni	Motors 1.0 year at 120°F. No visual defects in grains. Increase in P_c max and reduction in t_a at -65 and +165°F. One motor was scorched at forward motor tube—attributed to ignition flame confinement.

C. 23. 12 "Life Time Testing and Reliability of Solid Propellant Motors and Auxiliary Power Devices," Report No. NPP-TR-143, CSTAR X64-13726, U.S. Naval Propellant Plant, Indian Head, Maryland.

*This reference inadvertantly duplicated; see C. 23. 9.

C. 23 NPP (Continued)

C. 23. 13 "1964 Annual Report of the Quality Surveillance Division," AR 64 Report, U.S. Naval Propellant Plant, Indian Head, Maryland, 111 pp., 30 June 1965. (C)

To detect trends toward unsafe or hazardous condition and provide, if possible, proof that shelf life can be extended. Includes the following:

1) Guided Missiles—ASROC, Bullpup, Sidewinder 1A, Tartar, BT and HT Terrier
2) JATO Motors—2. 2KS-11, 000 and 0. 7-ES-2650
3) Ballistic Rocket Motors—2. 25-inch Mousetrap, 2. 75-inch FFAR, Weapon A
4) Aircraft Seat-Ejection Catapults—Rapec I and TALCO
5) Guided Missile Gas Generators—Sidewinder 1A, Sparrow III and Tartar/Terrier
6) Smokeless Powders (gun propellants).

C. 23. 14 J. Picard, "Surveillance Characteristics of XM-29 Propellant Currently Used in the Hawk and Sparrow Missile (U)," Report No. X65-11117 in Bulletin of 20th Interagency Solid Propellant Meeting, vol. IV, pp. 271-276, Picatinny Arsenal, Dover, New Jersey, October 1964. (C)

C. 23. 15 "1963 Annual Report of the Quality Surveillance Division," Report No. AR 63, U.S. Naval Propellant Plant, Indian Head, Maryland, 117 pp., 30 June 1964. (C)

Summarizes NPP work in 1963 in surveillance of fleet and depot stocks of units listed in Reference C. 23. 1.

C. 23. 16 "1962 Annual Report of the Quality Surveillance Division," Report No. AR 62, U.S. Naval Propellant Plant, Indian Head, Maryland, 31 July 1963. (C)

Surveillance of fleet and depot stocks of solid propellant units and related items. Summarizes work in 1962.

For units tested see Reference C. 23. 1.

C. 23. 17 M. F. Markley, "1961 Annual Report of the Quality Surveillance Division," Report No. AR 61, U.S. Naval Propellant Plant, Indian Head, Maryland, 99 pp., 11 May 1962. (C)

For units tested see Reference C. 23. 1.

C. 23 NPP (Continued)

C. 23. 18 C. P. Jones, "1960 Annual Report of the Quality Surveillance Division," Report No. AR 60, U.S. Naval Propellant Plant, Indian Head, Maryland, 5 April 1961. (C)

This annual report summarizes surveillance work conducted during the year on the following systems: Terrier BW-O, Sidewinder, 2.75-inch FFAR, 15KS-1000 Mk 6 JATO, Boar Booster Mk 6 Mod 0; work on other systems was delayed.

C. 23. 19 "Surveillance Division Report Covering the Years 1958 and 1959," Report No. AR 58/59, U.S. Naval Propellant Plant, Indian Head, Maryland, September 1960. (C)

This report covers surveillance on the following programs: Terrier Booster and Sustainer, ASROC, Sparrow Sustainer, Sidewinder 1A, 2.75-inch FFAR Motor, 5.0-inch SSR Motor, 2.25-inch SCAR Motor, 3.5-inch HEAT Rocket, Boar Booster, Regulus I Booster, JATO Mk 6 Mod 1, JATO Mk 7 Mod 1, Black Powder, 2.25-inch Projector Tail Charge, Igniter Test Chamber Development.

C. 23. 20 "Annual Report on the Quality Surveillance of Navy-Held Rocket Motors," QE/NPF 58-1, Naval Powder Factory, 60 pp., 9 figures, 11 tables, 1 July 1958. (C)

Summary report of the performance characteristics and quality of the 2.25-inch SCAR, 2.75-inch FFAR, 5.0-inch HVAR and 5.0-inch SSR motors.

C. 23. 21 J. Nanigan, "Annual Report on the Quality Surveillance of Navy-Held Rocket Motors," Report No. QE/NPF 57-1, Naval Powder Factory, Indian Head, Maryland, 36 pp., 2 tables, 6 figures, 15 February 1957. (C)

Summary report on all information available on the major types of rocket motors held in Navy inventory; summaries of malfunction reports received during 1956.

C. 23. 22 "Sampling Inspection and Test Programs for Quality Control and Surveillance of Military-Held Stocks of Missiles and Rocket Propulsion Units," Report No. AR 63, X64-15869, U.S. Naval Propellant Plant, Indian Head, Maryland.

C. 23. 23 J.F. Byrne and R.D. Risser, "Index of Naval Proving Ground Technical Reports Issued January 1954 - December 1955," Report No. 1440, U.S. Naval Proving Ground, 52 pp, distribution list, and abstract cards, 1 March 1956. (C)

This index includes a numerical listing together with an alphabetical subject, author and title index to formal reports prepared by the Naval Proving Ground during 1954 and 1955.

C. 19 TALOS (Continued)

C. 19.6 "Status of Development Projects (Cast Double-Base Propellant Motors," ABL/QPR No. 14, 15 April - 15 July 1959, Allegany Ballistics Laboratory, Cumberland, Maryland, 15 August 1959. (C)

Talos booster (5.8-DS-94200 X239B2) 120°F accelerated aging program was completed. Ambient storage up to 215 days with or without the nozzle closure had no adverse effect on the ballistic performance on an XM26E2 (Little John) unit. (See C. 10).

C. 19.7 "Status of Development Projects (Cast Double-Base Propellant Motors)," ABL/QPR 12, 15 June - 15 April 1959, Allegany Ballistics Laboratory, Cumberland, Maryland, 15 May 1959. (C)

Three Talos boosters (5.8-DS-94200 X239B2) stored at 120°F for 6 months were test fired.

C. 19.8 "Status of Development Projects (Cast Double-Base Propellant Motors)," ABL/QPR 8 (Contract NOrd 16640), Allegany Ballistics Laboratory, Cumberland, Maryland, 127 pp., 19 figures, 20 tables, 15 November 1958. (C)

Three X239B2 units completed a 6-month accelerated aging test of 120°F. A small amount of dark brown viscous fluid was removed from the bottom of the chambers.

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III-D. COMPONENT AND MATERIAL AGING REPORTS

The references presented in this subsection, dealing with components and materials that are common to most weapon systems, are valuable because they characterize the aging behavior of the various materials and thereby provide a basis for material selection in design and a basis for estimating the useful service life of the finished product. Information on material aging behavior will increase in value as more meaningful failure criteria are developed whereby the change in material properties with age can be correlated with system ageout and reliability degradation. The development of failure criteria is considered an essential requirement.

The references were selected to include the following information for each of the components and materials discussed in the paragraphs below:

- Aging characteristics
- Test methods (laboratory and functional)
- Accelerated versus natural aging
- Failure mechanisms and failure criteria

D.1 General

References in Subsection D.1 provide supplemental information which will be of value in the assessment phase (Phase II) of this program. Included are general survey reports on materials behavior, mechanism of failure, corrosion, and deterioration. The Prevention of Deterioration Center bibliographies on storage, effect of humidity, and general degradation are also referenced. There are several references outlining methods for statistically relating deterioration during storage or service to the operational reliability of the part and establishing the resulting effect on logistic support. The application of these statistical methods and techniques to the determination of the reliability degradation of propulsion systems will be assessed in the Phase II studies.

D.2 Adhesives/Bonding

References in Subsection D.1 pertain to bonds and adhesives. Among the areas included are failure mechanisms, evaluation reports, accelerated aging test results, bond detection methods, operational requirements, and aging data.

D.3 Elastomers

A large number of reports are available on elastomers, as noted in the references in Subsection D.3. These reports contain discussions on aging theory, basic material properties, accelerated aging, natural aging, evaluation techniques, and the effects of a humid, tropical environment. Several bibliographies and handbooks are also referenced. No attempt was made to include the many references available on ozone cracking except in the referenced bibliographies. The aging characteristics of elastomers are, in general, well defined except in relation to failure criteria.

D.4 Electrical Components

References in Subsection D.4 report on the reaction of electrical components to the high humidity environment of the tropics as well as general mechanisms of age-induced changes.

D.5 Reinforced Plastic Structures

Reviewed in Subsection D.5 are reports on filament-wound structures, reinforced plastics, and ablative materials. The reports contain studies on the material effects resulting from high humidity, compressive creep, and internal stresses. Bibliographies, guides to material selection, and test methods are included as well as reports on some experimental work to establish the aging characteristics of these materials. Additional references may also be found in the rocket motor development reports discussed in (A) and (C) of Section III.

D.6 Control Systems

A few reports on the long-term storage of Control Systems are listed in the References of Subsection D.6. The results of several studies including analysis of the "Lady Be Good" and "My Gal Sal" aircraft components indicate that the systems are usable after many years of inactive storage in rather unique environments.

D.7 Ignition Systems

The available literature on ignition systems, referenced in Subsection D.7, indicates that the aging of igniters is of concern. Included in this subsection are survey reports, discussions of failure mechanisms,

evaluation techniques, artificial aging tests, environmental tests, performance tests, surveillance results, ignition delay results, and data on the aging of squibs and igniter pellets.

D.8 Inhibitors/Liners

References in Subsection D.8 contain the available literature on inhibitors and liners as well as the reports dealing with interface reactions with the propellant. These references cover general survey reports, failure criteria, performance requirements, and bond evaluation techniques, in addition to the results of accelerated and natural aging studies on liners and the effects of age on case-bonding properties. The migration of nitroglycerin is discussed, together with techniques for determining its rate and effect on liner-propellant properties.

D.9 Ordnance Devices

The available literature of ordnance devices is given in the References of Subsection D-9. Further effort is planned to obtain more extensive information on the aging of ordnance devices.

D.10 O-rings/Seals

Many reports, referenced in Subsection D.10, are available on the aging characteristics of O-rings and seals, since those items have been considered the classical weak link of any system. Referenced in this section are the Rubber Manufacturers' Association program on the aging characteristics of O-rings which show the aging trends in O-ring physical properties. A number of the references attempt to deal with the problem of interpretating these physical property trends in terms of the function of the O-ring. In addition, reports are included correlating natural and artificial aging of seals, test methods for sealability, aging trends, and other seal aging data. The detailed bibliographies developed by the General Electric Company, as well as the handbooks developed by Boeing Airplane Company and Southwest Research Institute, are considered good review references.

D.11 Plastics/Insulation

The available reports on plastics and insulation aging are given in the references of Subsection D.11. Several of the referenced bibliographies provide valuable information regarding aging characteristics, stress cracking, radiation effects, storage stability, and testing techniques for plastic materials. Also included are reports on the performance requirements of insulation and compatibility with the propellant.

D.12 Propellants

References in Subsection D.12 are reports dealing with the aging characteristics of solid propellants, which are included even though this bibliography is not intended to cover propellant aging except as related to the propellant liner bond. Nevertheless, a bibliography on component aging would not be complete without some reference to propellant aging. In general, only review articles and key documents have been included.

D. 1 GENERAL

D. 1. 1 C. F. Bell, et al., "Some Elements of Planned Replacement Theory," I. E. E. Catalog No. 7C26, Proceedings, 1966 Annual Symposium on Reliability, San Francisco, January 25-27, 1966.

Investigates age at which operating parts of missiles and aircraft weapon systems should be replaced. Develops specific replacement policies for parts which fail according to one of the continuous probability distribution, i. e., normal, log-normal, and Weibull. Also develops replacement policies based on discrete probability distributions.

D. 1. 2 "Annotated Bibliography on Selected Topics in Materials Deterioration," Report No. PDC-Search-65-027-5, PDL-52380, Prevention of Deterioration Center, NAS-NRC, Washington, D. C., 126 pp., 11 November 1965.

D. 1. 3 J. Seremak, "Diaphragms, A Selected Bibliography," Report No. LS-BIB-65-1, N65-36500, Hughes Aircraft Co., Culver City, California, 14 pp., October 1965.

D. 1. 4 M. S. Geisler and C. F. Bell, "Increased Operational Capability Through Logistics Analysis," Report No. P-3233, AD622766, Rand Corp., Santa Monica, California, September 1965.

D. 1. 5 E. N. Pagh, "On the Mechanisms of Stress - Corrosion Cracking," Technical Report No. 65-7, AD620-513, N65-36246, Martin Company, Research Institute for Advance Studies, Baltimore, Maryland, 66 pp., August 1965.

D. 1. 6 "Prevention of Deterioration Center, Division of Chemistry and Chemical Technology," National Academy of Sciences, National Research Council.

Annotated bibliography on selected topics in materials deterioration. Presents definitive abstracts on deterioration of materials, grouped according to the following categories: Biological Agents and Control Methods; Ceramics, Cement Products and Glass; Electrical and Electronic Equipment; Lubricants and Fuels; Metals; Miscellaneous; Packaging and Storage; Organic Coatings; Plastics and Elastomers; Textiles and Cordage; Wood and Paper.

1. PDC Search No. 65-027-2, PDL-51959, AD460843, X65-16606, 15 March 1965; presents 91 abstracts on deterioration of materials.

2. PDC Search No. 65-027-3, PDL-52081, AD466839, X65-21086, 11 May 1965.

D. 1 GENERAL (Continued)

3. PDC Search No. 65-27-4, AD472423, 11 August 1965; Presents 155 abstracts on deterioration of materials; supplies bibliographic information for thirteen reports of related interest.

D. 1. 7 F. Coggegi, "Inspection of Lightweight Fueling-At-Sea Hoses Which Failed in Service," Report No. 84-9, Rubber Laboratory, Mare Island Naval Shipyard, Vallejo, California, 27 October 1965.

D. 1. 8 E. P. Klien, "Conditions of Failure in Fatigue-Cracked 4340 Steel," Report No. NRL-6317, Naval Research Laboratory, Washington, D. C., 7 October 1965.

D. 1. 9 D. J. Wulpi, "How Components Fail; Modes of Fracture," Metal Progress, vol. 88, PP 72-7, N65-35597, September 1965.

D. 1. 10 M. A. Schwartz, T. A. Greening, "Impregnated Foam Ceramic Insulation Materials," United Technology Center, Sunnyvale, California, in AFSC Summary of the Tenth Refractory Composites Working Group Meeting, pp. 401-431, August 1965.

D. 1. 11 V. F. Hribor, "Materials for Solid Rocket Motors," Technical Report No. PWW-TR-65-2, AD365745, Aerospace Corporation, El Segundo, California, 16 July 1965.

D. 1. 12 L. C. Montgomery, and H. E. Marsh, Jr., "Sterilized Solid Propellant Rocket Motors for Mars Landing Missions," Technical Report No. 32-725, Jet Propulsion Laboratory, (CIT) 30 June 1965.

D. 1. 13 "Bulletin of the 21st Interagency Solid Propulsion Meeting," Publication No. 71, Chemical Propulsion Information Agency Silver Springs, Maryland, 606 pp., June 1965. (C)

Semiformal conferences on the following (in part):

(1) Advance NDT Systems
(8) Elastomeric Insulation
(11) TVC
(13) Gas Generators
(14) Thermostability and surveillance of solid propellants.

D. 1. 14 C. Kuplent, et al., "Human Reliability Data," Report Nos. RHD-R64-1-2-3, RHD-R65-1-2-3, AD467909, IDEP 347.90.00. 00-G1-04, Rocketdyne Division, North American Aviation, Los Angeles, California, January 1965.

D. 1 GENERAL (Continued)

D. 1. 15 "Emerging Aerospace Materials," AFML-TR-65-114, AD463384, X65-16432, Air Force Materials Laboratory, Wright-Patterson AFB, Ohio, April 1965.

Briefly describes some of the more promising aerospace materials and processes resulting from recent research and development programs of the Air Force Materials Laboratory, including metals and alloys, seals and sealants, coatings and finishes, fibers and filaments, resins and adhesives, ablation materials, graphites, fluids and lubes, and miscellaneous materials. A list of recent handbooks related to these materials is also included. Describes proven or potential applications, limitations, and availability of the materials. This report intends to provide a consolidated review of promising materials for improved and future aerospace systems.

D. 1. 16 G. H. Lindsey, and M. L. Williams, "Structural Integrity of of an Ablating Rocket Subjected to Axial Acceleration," AIAA Journal, vol. 3, pp. 258-262, February 1965.

D. 1. 17 N. B. Levine, H. Krainman, and J. E. Rathgeb, "Positive Expulsion Bladders for Storage Propellants," Report period 15 May 1964 - 1 August 1964, RMD-5052-Q1, AD457620; Report period, 1 August 1964 - 1 November 1964, RMD-5052-Q2, AD457619, X65-31201.

Evaluation of candidate elastomers for long term resistance to hydrazine/UDMH is continuing, and the effect of these elastomers on decomposition of the fuel blend has been determined. Discusses fabrication of an all-rubber expulsion bladder by bag-molding and dip-molding.

Describes fixture and procedure for ultrasonically welding aluminum foil on a spherical, water-soluble mandrel. Dip-coating studies for applying butyl rubber to aluminum foil have been initiated. Discusses the optimization of procedures for annealing and sealing pinholes in aluminum foil.

D. 1. 18 J. G. Horton, II, "Experimental Evaluation of Solid Propellant Rocket Motors under Acceleration Loads," Journal of Spacecraft and Rockets, vol. 1, pp. 673-675, November-December 1964.

D. 1. 19 "Mathematical and Engineering Prediction of Equipment Service Life," Report No. APJ-373-1, AD469963, American Power Jet Company, Ridgefield, New Jersey, October 1964.

Describes methods for more accurately predicting useful life span of Naval mechanical and electrical equipment utilizing basic failure mechanisms, multiple regression, and time variant hazard rates.

D. 1 GENERAL (Continued)

D. 1. 20 B. B. Winter, et al., "Accelerated Life Testing of Guidance Components," AL-TDR-64-235, AD448079, X65-10125, Autonetics Corp., Anaheim, California, 30 September 1964.

Describes and analyzes currently prevalent approach to accelerated testing, which is found inadequate. Presents comparative discussion of various failure models, with those most amenable to meaningful accelerated testing developed in detail. Describes models for devices with multiple failure modes, and reviews pertinent estimation procedures. Presents a new method for efficient estimation of the failure distribution of repairable equipment. Also includes detailed examination of several space guidance components, with emphasis on considerations pertinent to accelerated testing, and recommends specific applications of accelerated testing to space guidance components. Examines the phenomenon of metallic creep from the standpoint of its relation to failures of space guidance components, and methods of accelerated estimation of creep behavior.

D. 1. 21 N. E. Frost, "The Effect of Environment on the Propagation of Fatigue Cracks in Mild Steel," Applied Materials Research, vol. 3, pp. 131-138, July 1964.

Discusses the fatigue strength of certain materials, obtained by testing specimens either in a high vacuum with their surfaces protected from the atmosphere, known to be higher than the normal air fatigue strength. Also investigates the effect of keeping the atmosphere away from the specimen surface on the cyclic stress necessary to initiate surface cracks, and on their subsequent rate of growth.

D. 1. 22 M. T. Shoughnessy, "Polymers in Missile and Space," Transcription of 9th Symposium on Ballistic Missiles and Space Technology, vol. II, 1964, Aerospace Corporation, El Segundo, California, Materials Science Laboratory Report No. X65-13613, 20 July 1964.

D. 1. 23 H. M. Blaes, et al., "Application of Materials to Advanced Rocket Nozzle and Hot Gas Control Systems," Philco Corporation, Research Laboratory, Blue Bell, Pennsylvania, Fourth Quarterly Report, AD464980, X65-14844, 15 July 1964.

Laboratory experiments conducted to determine recession rates of candidate nozzle materials using high pressure, high temperature, and convective flow. Oxidation characteristics of a zirconium boride-graphite-silicon composite were continued. Tin-aluminum coatings were evaluated in liquid propellant combustion product simulations at typical chamber pressures. Discusses a continuation of the analysis of the shear strength test of reinforced plastic materials during ablation.

D.1 GENERAL (Continued)

D.1.24 V.D. Celantano, "Aging Characteristics of Minuteman Polyurethane Binders," AFBSD Technical Note TDR 64-52, under Contract AF 33(600)-36610, Aerojet-General Corp. May 1964.

D.1.25 H. Joinecka, "Preservation of Inactive Equipment and Long-Term Storage of Materials," a bibliography, PDC 63-045, PDL 49630, AD600642, Prevention of Deterioration Center, NAS-NRC, Washington D.C., 1 November 1963.

D.1.26 C.H. Parr, "Viscoelastic Cylinders of Complex Cross Section Under Axial Acceleration Loads," AIAA Journal, vol. 1, pp. 2404-2406, October 1963.

D.1.27 P.D. Gray, "Rockets In Space Environment," vol. I - The Experimental Program, Technical Documentary Report No. RTD-TDR-63-1050, Aerojet-General Report No. 2484 (Final Report), Aerojet-General Corporation, Azusa, California, February 1963.

Objective was to establish design criteria for space propulsion systems.

D.1.28 R.L. Taylor, "Problems in Thermoviscoelasticity," Univ. of California (Berkeley) Institute of Engineering Research Report under Lawrence Radiation Laboratory, P.O. No. 1206700, January 1963.

D.1.29 L.A. Weaver, and M.P. Smith, "The Life Distribution and Reliability of an Inertial Guidance System," Proceedings of 8th National Symposium on Reliability and Quality Control, 1962.

D.1.30 W. Weiss, "Reliability of a System in Which Spare Parts Deteriorate in Storage," Journal of Research, National Bureau of Standards, vol. 66B, no. 4, October, December 1962.

Considers the failure statistics for a system in which failures occur at different rates in use and in storage. The resulting equations can be solved explicitly when both types of failures follow Poisson's Law.

D.1.31 R.D. Brown, "An Annotated Bibliography of Polaris/Minuteman/Pershing Nondestructive Committee Meeting Presentations," SPIA B7, SPIA, Silver Springs, Maryland, 86 pp. November 1962. (C)

D.1.32 R.W. Lee, "Selected Literature References on Critical Relative Humidities for Corrosion and Fungus-Free Storage," PDC 62-038, PDL 44499, Prevention of Deterioration Center, NAS-NRC, Washington, D.C., August 1962.

D.1.33 F.R. Larson, and J. Miller, "A Time-Temperature Relationship for Rupture and Creep Stresses," Transactions of the American Society of Mechanical Engineers, 74, pp. 765-775, July 1962.

D. 1 GENERAL (Continued)

D. 1. 34 W. L. Rollwitz, "Radio Frequency Spectroscopy," Bulletin of 6th Meeting of JANAF-ARPA-NASA Solid Propellant Surveillance Panel, December 1961.

D. 1. 35 G. N. Lewis, "Current Status of Failure Criteria Studies," Committee of the JANAF-ARPA-NASA Solid Propellant Surveillance Panel, December 1961.

D. 1. 36 L. D. Jaffe, and J. B. Rittenhouse, "Behavior of Materials In Space Environments," Technical Report No. 32-150, Jet Propulsion Laboratory, 1 November 1961.

D. 1. 37 M. Levitsky, and B. W. Shaffer, "The Temperature Distribution in a Case-Bonded Cylindrical Rocket Assembly," N. Y. U. Technical Report for Allegany Ballistics Laboratory, under Contract NOrd-16640, September, 1961.

D. 1. 38 W. H. Walters, "Permeation Propellants Through Bladders," AD288204, March 1962, AD288203, Bell Aerosystems, Buffalo, New York, June 1961.

D. 1. 39 W. E. Berry, "Stress-Corrosion Cracking—A Nontechnical Introduction to the Problem," Report No. 144, Defense Metals Information Center, Battelle Memorial Institute, Columbus, Ohio, 28 pp., January 1961.

Reviews the problem of stress corrosion cracking from a nontechnical viewpoint, and the recognition of this form of corrosion cracking. Environments most likely to cause stress corrosion cracking are pointed out. The action of material composition, stress, environment, temperature, and time on stress corrosion cracking is discussed and suggestions made for controlling these variables. Also considers roles of protective coatings, inhibitors, and cathodic protection in reducing cracking susceptibility. Includes a bibliography of 122 references.

D. 1. 40 J. H. Kao, "Summary of Some New Techniques on Failure Analysis," Proceedings of 6th National Symposium on Reliability and Quality Control, 1960.

D. 1. 41 Quarterly Summary Reports 38-1 and 38-2, Jet Propulsion Laboratory, August 31, 1960 and December 31, 1960. (C)

D.1 GENERAL (Continued)

D.1.42 J.C. Farber, et al., "Super C Sustainer (X234) and Interim Super C Sustainer (X213J4)," MPR Nos. 52, 54-60 (Contracts NOrd 10431, 16640), Allegany Ballistics Laboratory, Cumberland, Maryland, October 1956. (Also see Nos. 15, 633.) (C)

MPR 54, 55, 56, 57: 100 Tapco in-flight arming switches were tested under different conditions; some were noted for improvements. MPR 58: results of an igniter study indicated the present igniter produced too low pressure at -40°F to promote immediate burning of the propellant. MPR 60: The igniter program at -40°F indicated that this temperature is too low for the present squib-diverter ignition system.

D.1.43 E.G. Bodine, et al., "Interaction of Bearing and Tensile Loads on Creep Properties of Joints," Note 3758, National Advisory Committee for Aeronautics Technicians, 23 pp., 12 figures October 1956.

Describes studies made on the interaction of bearing and tensile loads on the creep behavior of joints. A specimen was designed which possessed some of the general features of pin and rivet joint connections.

D.1.44 J.D. Ramsdell and A.T. Robinson, "Strength Evaluation of Welded Thin-Wall Steel Tubing for Rocket Motors," NOTS 1331 NAVORD Report 4999, U.S. Naval Ordnance Test Station, China Lake, California, 18 pp., 4 tables, 5 figures, 16 July 1956. (C)

Welded AISI 1030 cold-rolled mandrel-drawn steel tubing evaluated was not strong enough to replace aluminum tubing on a weight-for-weight basis in existing rockets.

D.1.45 "Shelf Life of Lined Motor Cases," QPR No. 21-56, Thiokol Chemical Corp., Huntsville, Alabama, June 1956. (C)

The useful shelf life of unloaded rocket engines lined with J liner may be considered to be at least 58 days.

D.1.46 M.A. Miner, "Cumulative Damage in Fatigue," Transactions of the American Society of Mechanical Engineers, 67, A 159, 1945.

D.1.47 "Service Life Test of the Track Jettison Cartridge P/N AMF 105-017-2400," Report No. AD 415408, Ogden Air Material Area, Hill AFB, Ogden, Utah.

D.1 GENERAL (Continued)

D.1.48 R. Winer, "Panel on Quality Control in Large Solid-Propellant Rockets," SPIA, Bulletin of the 14th Meeting. JANAF Solid Propellant Group, Addendum, pp. 1 - 56, Allegany Ballistics Laboratory. (C)

1. Reliability Program for Polaris Propulsion Subsystem, Aerojet-General Corp.
2. Surveillance of large, solid propellant motors.

D.1.49 J.N. Sherman and H.R. Conrad, "Rocket Temperatures Under Actual Exposure to Climatic Extremes," SPIA, 12th JANAF Solid Propellant Group Meeting Bulletin Addendum, Allegany Ballistics Laboratory, Cumberland, Maryland 26 pp., May 1956. (C)

A 16-inch rocket stored in the desert during the summer of 1954 indicated that the extremely high upper temperature limits which are so frequently specified are unrealistic. A similar cold weather program was also conducted.

D.1.50 R.E. Angerman and R.A. Patterson, "General Designs and Fabrication Techniques Employed in Producing Missile Boosters, Sustainers, JATOS and Related Items," (Contract NOrd 15719), Paper Study of Fabrication Techniques, Ingersoll Kalamazoo Division, Borg-Warner Corporation, 1955. (C)

The general outline of fabrication and design used on 5 missile boosters and two missile sustainers. Units include JATO 4-DS-105,000, X202D1, Snark booster; JATO 1.8-DS-7000, X205A3, Rat Booster; JATO 20-DS-2350, X213F1, Terrier sustainer; JATO 20-DS-2350, X213J1, Terrier sustainer; JATO 2.5-DS-59,000, X216B1, Terrier booster; JATO 2.5-DS-59,000, X216E2, Terrier booster; and JATO 2.5-DS- 59000, XM5, Nike Booster.

D. 2 ADHESIVES/BONDING

D. 2. 1 K. W. Bills, Jr., et al., "A Cumulative Damage Concept for Propellant-Liner Bonds and Its Application to Solid Rocket Motors," presented at the Sixth Solid Propellant Rocket Conference, AIAA, Washington, D. C., February 1965; in press, Journal of Spacecraft and Rockets, 1965.

D. 2. 2 R. E. Keith, R. E. Monroe, D. C. Martin, "Adhesive Bonding of Titanium and its Alloys," NASA Technical Memo; RSIC TM-X-5313; 414, Battelle Memorial Institute, Columbus, Ohio, 4 August 1965.

D. 2. 3 J. I. Gnapp, "Experimental Strain Analysis of Combination Adhesive/Bolt Joints Between Glass-Reinforced Plastic Laminates," Report No. PA-TR-3131, AD 467942, Picatinny Arsenal, Dover, New Jersey, August 1965.

D. 2. 4 R. F. Wegmon and E. L. O'Brien, "Response of Epoxy Adhesives When Stressed to Failure in Milliseconds," Report No. PA-TR-3122, AD 465230, X65-19013, Picatinny Arsenal, Dover, New Jersey, June 1965.

D. 2. 5 M. D. Anderson, "Preliminary Evaluation of 22 Commercial Structural Adhesives," Report No. PA-TM-1574, AD 465113, X65-19279, Picatinny Arsenal, Dover, New Jersey, June 1965.

Evaluation of 22 adhesives for use on Army materials, including the bond strength to aluminum at -54°, 23°, and 71°C and after exposure to accelerated environmental testing.

D. 2. 6 B. J. Taylor and W. C. Wake, "A Survey of Literature on High Temperature Metal-to-Metal Organic Adhesives, February 1964-January 1965," London Ministry of Aviation, Report No. 125, Rubber and Plastics Research Association of Great Britain, Shewsbury, England, April 1965.

D. 2. 7 R. F. Wegman, "Effect of Surface Preparation and Aging Time on Epoxidized Novalac Bonds to Stainless Steel," Report No. PA-TM-1548, AD 460681, X65-16246, Picatinny Arsenal, Dover, New Jersey, April 1965.

Discusses aging of adhesives.

D. 2. 8 C. Gustevson and T. W. Greenlee, "Solid Propellant Adhesion," Report No. 0752-81Q-151, Aerojet-General Corporation, Sacramento, California, 30 August 1963. (C)

Review of pertinent literature and technology

D. 2. 9 E. E. Unger and B. W. Shaffer, "Thermally Induced Bond Stresses in Case-Bonded Propellant Grains," ARS Journal, pp. 366-368, April 1960.

D. 2 ADHESIVES/ BONDING (Continued)

D. 2. 10 W. W. Brandon, et al., "Quarterly Progress Report on Interior Ballistics," Report No. P59-1, Rohm and Haas Company, Huntsville, Alabama, 31 August 1959. (C)

Mathematical analysis of the possibility of using infrared photography for the detection of case bond failures.

D. 2. 11 "Study of Large Solid-Propellant Rocket Motors," Report No. 1785/89, Final, vol. 3, April 1956-March 1958, (Contract AF 04(647)-69) Aerojet-General Corporation, Sacramento, California, 70 pp., figures and tables, 15 August 1958. (C)

Evaluations of adhesives and chamber sealing materials. Literature survey, including annotated bibliography on thrust-vector control devices.

D. 3 ELASTOMERS

D. 3. 1 Z. T. Ossefort, "Accelerated Heat and Oxygen Aging of Rubber," TR 55-1993, AD 66097, Rock Island Arsenal, Rock Island, Illinois, 18 May 1966.

D. 3. 2 F. R. Mayo and K. C. Irwin, "Accelerated Deterioration of Elastomers," Final Report, Stanford Research Institute, Menlo Park, California, 30 March 1965.

Part 1, degradation in solution AD460614, X65-14337.

Part 2, experiments with vulcanized rubbers, AD 460615 X65-12448.

Report seeks ways to degrade elastomers rapidly at room temperature: Part 1 concerns accelerated oxidation of solutions of polyisoprene; Part 2 describes experiments on vulcanized natural rubber with pro-oxidants which were most effective in solution.

D. 3. 3 M. L. Williams, "Failure Criteria for Visco-Elastic Materials," 1 July-31 December 1964, NASA-CR-60896, GALCIT-SM-65-2, X65-12893, California Institute of Technology, Graduate Aerosciences Laboratory, Pasadena, California, January 1965.

D. 3. 4 H. L. Nash and J. C. Collyer, "The Aging and Weathering of Rubber Compounds," Report No. DCBRL434, AD443806, Defense Chemical Biological and Radiation Laboratory, Ottowa, Canada, May 1964.

D. 3. 5 A. Cosgarea, R. K. Martenson, and R. W. Vaughn, "Aging of Cure-Dated Items and Various Elastomeric Compounds," Report No. AD 432369, Oklahoma University Research Institute, Norman, Oklahoma, for Oklahoma City Air Materiel Area, Tinker AFB, Oklahoma City, Oklahoma, 30 September 1963.

Nitrile rubber stocks from various rubber companies were examined and aged under various conditions. Under study conditions, elongation of nitrile rubber stocks was predicted to decrease 20 percent of the original value in 8.5 years at a temperature of 25°C. The study is also reported in: "Accelerated Aging Experiments with Paracril-D and Hycar 1001 Rubber Stocks," by A. Cosgarea and L. E. Trimble. Interim Report on Project 1384-6.

D. 3. 6 E. W. Bergstrom, "Six-Year Indoor and Outdoor Aging of Elastomeric Vulcanizates," TR 63-2392, Rock Island Arsenal, Rock Island, Illinois, 16 July 1963.

D. 3 ELASTOMERS (Continued)

D. 3. 7 A. G. Pickett and M. M. Lencoe, "Handbook of Design Data on Elastomeric Materials Used in Aerospace Systems," ASD TR61-234, AD272880, Southwest Research Institute, San Antonio, Texas, January 1962.

A design handbook of useful data on properties of elastomers, including the changes in mechanical and physical properties that result from aging and exposure to environments of aerospace weapons systems.

D. 3. 8 E. W. Bergstrom, "Indoor and Outdoor Aging of Elastomeric Vulcanizates Over a Ten-Year Period," TR 61-3868, Rock Island Arsenal, Rock Island, Illinois, October 1961.

Properties of SBR, CIR, NBR, and IIR vulcanizates were determined during aging indoors and outdoors over a period of ten years.

D. 3. 9 J. G. Tuono, and W. M. Vogel, "Two Apparatuses for Investigating Elastomers: 1. Relaxometer; 2: Vapor Pressure Apparatus," Bulletin of 18th Meeting of JANAF Panel on Physical Properties of Solid Propellants, SPIA/PP 12, June 1959.

D. 3. 10 "Bibliography on Aging of Natural and Synthetic Rubber and Rubber Products in Storage," PDC S61016 PDL 49379, AD 601284, Prevention of Deterioration Center, NAS-NRC, Washington, D. C., May 1961.

D. 3. 11 "Missile Systems Elastomers - Predicting Field Life Expectancies," ASME Paper 61-AV-26, 1961, Prepared by Chrysler Corp., Missile Division, March 1961.

D. 3. 12 D. H. Kallas, "Investigation of Shelf Aging of Synthetic and Natural Rubber Materials," Report No. 5974, Parts 1 and 2, AD 229186L, U. S. Navy Material Laboratory, New York Naval Shipyard, 18 May 1959. (See also Report No. 5974, Parts 3 and 4, AD 221461, 3 December 1959.)

Summarizes test procedures for artificial aging in comparison with natural aging of elastomers.

D. 3. 13 J. Mondel, et al., "Measurement of the Aging of Rubber Vulcanizates," Journal of Research of the National Bureau of Standards, vol. 63c, No. 2, October-December 1959.

Results indicate that ultimate elongation is the best tensile property to characterize deterioration of rubber during storage. Includes a study of the results of tests conducted by subcommittee 15 of ASTM Committee D-11, involving vulcanizates of five different rubbers stored at different temperatures.

D. 3 ELASTOMERS (Continued)

D. 3. 14 C. Bailys, "Final Report on Tropical Environment Tests of Standard Elastomer (Rubber) Samples," Report No. DA-58-R10, Chrysler Corp., Missile Division, 31 March 1959.

D. 3. 15 E. W. Bergstrom, "Aging of Unstressed Elastomeric Vulcanizates During Outdoor and Controlled Humidity Exposures," Report No. TR 58-1808, AD203551, Rock Island Arsenal, Rock Island, Illinois, July 1958.

Reports on 7-year humidity aging program and on 6-year outdoor aging program.

D. 3. 16 J. M. Buist, "Aging and Weathering of Rubber," W. Heffer and Son, Ltd., for the Institution of the Rubber Industry, Cambridge, England, 1956.

Monograph on theory and practical effects of aging.

D. 3. 17 "Literature Survey on Aging and Storage of Vulcanized Rubber Goods," Battelle Memorial Institute, Columbus, Ohio, May 1946.

D. 3. 18 "Nondestructive Aging Tests for Rubber," Analytical Chemistry, vol. 23, pp. 16-19, November 1951.

Describes the development of a strain tester for evaluating the effects of aging.

D. 3. 19 "15-Year Shelf Aging Test of Neoprene," du Pont's Elastomers Notebook 102, du Pont Elastomer Department, du Pont Corp.

An investigation of small flexible couplings showed natural rubber stiffened approximately three times as much as the neoprene after shelf aging for 15 years.

D. 3. 20 "Annotated and Indexed Bibliography on Stress Cracking of Elastomers," Report No. PDC-64-026-1 PDL 51553, X64-17713, Prevention of Deterioration Center, NAS, NRC, Washington, D. C.

D. 3. 21 "Standardization Program on Shelf-Aging of Synthetic and Natural Rubber Materials," Naval Applied Science Laboratories, Brooklyn, New York, LP 5974, AD 416304.

Final report of a 5-year aging program on GR-S, Buna-N, natural and neoprene stocks. Tensile product (tensile strength multiplied by percent elongation) as well as 300 percent modulus where consistent indicators of deterioration. Concludes that 10 weeks at 140°F in a Greer oven is more severe than 5 years natural aging.

D. 3 ELASTOMERS (Continued)

D. 3. 22 A Cosgarea and L. E. Trimble, "Accelerated Aging Experiments with Poracril-D and Hycor 1001 Rubber Stocks," Interim Report on Project 1384-6, University Research Institute, Norman, Oklahoma, for Oklahoma City Air Materiel Area, Tinker AFB, Oklahoma.

(Also See Reference D. 17. 10.)

D.4 ELECTRICAL COMPONENTS

D.4.1 A. F. Fini and W. B. Morrow, "Tropical Service Life of Electronic Parts and Materials," Final Report 8, 1 May 1963, AD470702, Malpar Inc., Falls Church, Virginia, 30 April 1965.

Reliability of electronics parts and materials used under tropical environment, including 55,000 data points; computer program is being developed on another contract.

D.4.2 I. T. Turner, (Martin Company, Orlando, Florida), "Corrosion of Electrical Equipment by Plastics," Material Protection, vol. 3(9), pp. 48-52, September 1964.

Discusses vaporization of insulation as a possible cause of unexplained malfunction or failure of electromechanical systems in missile and other equipment. Failure may result from short circuits or overloads during systems testing. Tests were carried out to determine corrosion caused by insulating materials vaporized under short circuit conditions.

D.4.3 R. B. Belser and W. H. Hicklin, "Quar[illegible] [illegible]tal Aging Effects," Report No. 7 (Quarterly Report), AD463[illegible] Georgia Institute of Technology, 15 August 1964 - 15 November 1964.

Purpose of research is to reduce aging and failure rates of quartz resonators, thereby increasing reliability. Investigation will examine effects of various materials, fabrication techniques, and operating conditions on aging and reliability; effects of exposure to selected types of radiation, principally gamma radiation, will be determined. In addition, low frequency units of 100-500 kc range will be examined.

Of particular interest is the effect of differences among various types of quartz (natural, swept natural, cultured, and swept cultured quartz) on the long term aging of resonators and on the differences in behavior of the various resonators after irradiation.

D.4.4 G. P. Chipman and K. E. Hassler, (Battelle Memorial Institute), "Laboratory Test Procedures for Predicting the Tropical Service Life of Electronic Components and Materials," Contract DA-36-039-SC-64518, 12th Quarterly Progress Report, 99 pp. U.S. Signal Corps, November 1957.

Summarizes data on 19 basic electronic components exposed for over 2 years in Panama. By establishing criteria of operational failure for the components (as opposed to catastrophic failure), the mean component life under tropical exposure is equated with the mean component life as determined by a laboratory temperature-humidity cycle.

D.4.5 J.A. Kok and M.M.G. Corbey (N.V. Philips' Gloeilampenfabrieken, Eindhoven, Netherlands), "Breakdown of Liquid Insulating and Dielectric Material," Applied Scientific Research, vol. 6B, pp. 197-206, 1956.

A possible cause of long term breakdown of low frequency impregnated paper capacitors and cables is the slow formation of a conducting bridge between the electrodes, followed by a short time thermal breakdown. The bridge may consist of polarizable particles, ions, or colloidal contaminants of high dielectric constant, particularly conducting materials. The postulated mechanism applies to both liquid and solid dielectric materials.

D. 5 GLASS-REINFORCED STRUCTURES (FILAMENT-WOUND CHAMBERS)

D. 5. 1 B. W. Abbott, R. W. Cornish, "Further Observations on the Bi-axial Compressive Creep Performance of Filament Wound Laminates," Special Technical Report IITRI-M6081, AD466784, Illinois Institute of Technology Research Institute, Technical Center, Chicago, Illinois, 1 September 1964-30 June 1965, July 1965.

Results of a study in progress for 2 years of closed-end cylinders subjected to external pressure.

D. 5. 2 "Evaluation of Testing Techniques for Filament-Wound Composites," Quarterly Report No. 3, December 1964-March 1965, AD464828, X 65-19849, Thiokol Chemical Corp., Brigham City, Utah, 31 March 1965.

Primary objectives of the Air Force Research and Technology Program are to evaluate existing test methods and supporting data used within the fiberglass industry and to recommend testing techniques for acceptance as standards by the industry and the military. The program is divided into the following six work tasks.

Task I	-	Analysis of Problem
Task II	-	Screening of Test Methods
Task III	-	Statistical Evaluation
Task IV	-	Test Program
Task V	-	Test Method Recommendations
Task VI	-	Liaison Effort

D. 5. 3 S. Breiant, I. Petker, and K. W. Smith, "Combined Effects of Pre-Stress and Humidity Cycling Upon Filament-Wound Internal Pressure Vessels," Society of Plastics Engineering Journal; vol. 20, pp. 1019-1023, September 1964.

Epoxy resins coupled with HTS finish on E glass give excellent environmental protection to glass fibers in reinforced plastic composites. The resin matrix, however, must be free of cracks and relatively free of voids. When subjected to a uniaxial stress field, the protective system appears to remain intact up to the ultimate strength of the material.

Filament-wound, bi-axially-stressed composites show the same order of protection unless these composites are stressed prior to environmental exposure (95 percent RH with temperature cycling from 68-168°F). During pre-stress, cracks occur in the resin of bi-axially-loaded composites which can cause breakdown in the environmental protective system. After pre-stresses as low as 40 percent of ultimate burst, the composite is subject to relatively rapid environmental degradation.

D. 5 GLASS-REINFORCED STRUCTURES
(FILAMENT-WOUND CHAMBERS) (Continued)

D. 5. 4 A. M. Shibley, "Filament Winding Bibliography: Evaluated and Annotated," PLASTEC Report 19, Plastics Technical Evolution Center, Picatinny Arsenal, Dover, New Jersey, December 1964.

D. 5. 5 C. A. Bowe, "Microscopic Study of Mode of Fracture in Filament-Wound Glass-Resin Composites," Memoranda on NRL Project 62RO5-19, T. and A. M. Report No. 234, University of Illinois, Urbana, Illinois, 53 pp., November 1962.

D. 5. 6 "Predicting Service Life of Plastics," Plastics Technology, p. 26 October 1962.

D. 5. 7 J. A. Matta, and J. O. Outwater, "The Nature, Origin, and Effects of Internal Stresses in Reinforced Plastic Laminates," Memorandum on NRL Project 62 RO5-19, Technical Memo No. 176, University of Vermont, Burlington, Vermont, 31 October 1961.

Tension set up between epoxy resin and glass is found to remain constant with time, and is linearly dependent on the highest temperature to which the resin has been brought during or after cure.

D. 5. 8 J. O. Outwater and O. Oszaltin, "The Surface Effects of Various Environments and Thermosetting Resins on Glass," Memoranda on NRL Project 62 R 05-19, Technical Memorandum No. 174, University of Vermont, Burlington, Vermont, 5 October 1961.

Main effort to determine strength reduction in reinforced plastics; etched glass rods were subjected to various environments. An increase in strength was reported when the glass surface was treated with Union Carbide A-1100 or Owens-Corning 801 before resin was applied.

D. 5. 9 "Design Considerations in Selecting Materials for Large Solid-Propellant Rocket Motor Cases," DMIC Report 180, Defense Metals Information Center, Battelle Memorial Institute, Columbus, Ohio, December 1960.

D. 5. 10 "Research and Development Work on Cast Double-Base Propellant Rockets," Imperial Chemical Industries, Ltd., U. K. Monthly Reports, July-October 1958. (C)

Storage of fiberglass motor cases at 125°F and 100 percent relative humidity.

D. 5. 11 "Research and Development of Inert Components for Rocket Cases," Summary of Progress, Report No. GER-6927, Goodyear Aircraft Corporation, 22 pp., 2 tables, 11 figures, 20 September 1954-20 March 1955. (C)

Investigations include a detailed discussion of the X205X1 case deterioration after 17 days of storage at 140°F and 95 percent relative humidity. As a result of this program, ABL initiated a new program to evaluate improved X205X1 units.

D. 5 GLASS-REINFORCED STRUCTURES
(FILAMENT-WOUND CHAMBERS) (Continued)

D. 5. 12 "A Survey of Filament Windings: Materials, Design Criteria, Military Applications," PLASTEC Report 10, Plastics Technical Evaluation Center, Picatinny Arsenal, Dover, New Jersey.

D. 5. 13 K. W. Smith, "Environmental Effects on the Structural Perfection of Filament-Wound Components," Bulletin of 21 ISP Meeting vol. I, AD360462, Aerojet-General Corporation, Sacramento, California.

D. 5. 14 J. D. Outwater and W. J. Seibert, "On the Time Dependence of Failure of Filament-Wound Pressure Vessels," Technical Memorandum No. 193, University of Vermont, Burlington, Vermont.

D. 6 CONTROL SYSTEMS

D. 6. 1 "Long Term Storage of Missile Hydraulic Systems," Report No. D2-84175-1, study conducted by The Boeing Company, Seattle, Washington, 25 March 1966.

Summarizes the pertinent results of long-term storage testing of hydraulic systems which affect missile storage capability. Test results are topically separated to independently discuss storage effects on fluids, seals, hydraulic components, and hydraulic systems. Comments are made concerning the applicability of the test results and regarding design practice for storability. Conclusions are drawn regarding inactive storage of hydraulic systems for at least a 5-year period.

D. 6. 2 L. McClure, "Thrust Vector Control, Selected Bibliography," Report No. RB-119, AD 463150, Martin Company, Orlando, Florida, 6 May 1965.

(Also see Reference D. 2. 1, "Adhesives/Bonding")

D. 6. 3 N. N. Fruktow and L. E. Gatzek, "Long Term Storage of Hydraulic Thrust Vector Control Systems," Institute of Environmental Sciences Proceedings, pp. 321-334, April 1962.

D. 6. 4 "Evaluation Report, B-24-D 'Lady Be Good' Hydraulic Components," Report No. WWFESM-60-21, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, 29 March 1961.

D. 6. 5 "Investigation of Hydraulic Equipment Removed from B-24-D 'Lady Be Good' Aircraft," Vickers, Inc., Los Angeles, California, 7 July 1960.

D. 6. 6 R. J. Mulvihill, et al., "Compilation and Analysis of Calendar-Age Related Data for Hydraulic Systems Components," Report No. PRC R-377, IDEP 347.20.00.00-E2-01, Planning Research Corporation, Los Angeles, California.

Results of a study to compile and analyse data concerning long-term storage capability of hydraulic system components. Areas covered include gas generators, igniters, squibs, batteries, TVC systems, motors, pumps, check valves, actuators, servo valves, filters, accumulators, power suppliers, elastomers, and hydraulic fluids.

D. 7 IGNITION SYSTEMS

D. 7. 1 A. C. Bauer, "Performance of V. T. Fuzes, MK 72 and MK 71 versus Fuze Age, Storage Conditions, and Firing Temperatures," Summary Report, 27 July-August 1964, NOL TR-65-78, AD365211L, Naval Ordnance Laboratory, White Oak, Maryland, 3 June 1965.

D. 7. 2 Howard M. Bunch, "A Study and Comparison of Temperate, Arctic, and Desert Tests of Mechanical Time Fuzes," Contract DA-23-072-509-ORD-8, Project DA1A650212D622, Southwest Research Institute, San Antonio, Texas, 15 November 1963.

D. 7. 3 "Solid Propellant Igniter Design Handbook, " published under direction of The Chief of the Bureau of Naval Weapons, published by CPIA, Bermite Powder Company, Saugus, California, NAVWEPS Report 8015, 17 April 1961. (C)

Chapter 2 discusses effects of age and environment on ignitability.

D. 7. 4 Quarterly Progress Report of Army Supporting Research (Propellant Research and Development), Report No. 20-59, January-March 1959, Thiokol Chemical Corp., Redstone Arsenal, Redstone, Alabama, 28 August 1959. (C)

Test program determined aging characteristics of various squibs after storage for a maximum of 125 weeks at 70°F in an ammonia atmosphere, and for 142 weeks at 160°F. After 4 years of storage in an igloo, four 5-inch motors ignited with longer than normal ignition times. Studies were conducted to determine whether phosphating would prevent rusting of steel.

D. 7. 5 J. Nanigian, "Surveillance Evaluation of Igniters in Missile Booster 2. 2-KS-33,000 (X105H1)," Report No. QE/NPP 58-7, U. S. Naval Propellant Plant, Indian Head, Maryland, 9 pp., 10 October 1958. (C)

Describes surevillance testing of the Alclo pellet igniter used in missile booster 2. 2-KS-33, 000 (X105H1). Concludes that all igniters be replaced in the X105H1 motor.

D. 7. 6 "Quarterly Progress Report (Composite Propellant and Rocket Development)," (1958), Report No. 1-58 (Report No. C-C-58-3) (October-December 1957), Thiokol Chemical Corp., Redstone Arsenal, Redstone, Alabama, 95 pp., 28 tables, 77 figures, 3 appendices. (C)

Reports on the aging of squibs for 66 and 79 weeks in ammonia atmosphere.

D. 7 IGNITION SYSTEMS (Continued)

D. 7. 7 "Quarterly Progress Report (Composite Propellant and Rocket Development)," Report No. 30-57, Thiokol Chemical Corp., Redstone Arsenal, Redstone, Alabama, 63 pp., 31 figures, 21 tables, appendices, April-June 1957. (C)

Three new squib designs were aged both at 160°F for 35 to 44 weeks and functioned normally; motor aging for 23 months at 140°F.

D. 7. 8 "Quarterly Progress Report (Composite Propellant and Rocket Development)," Report No. 40-57 (Quarterly), Thiokol Chemical Corp., Redstone Arsenal, Redstone, Alabama, 81 pp., 29 tables, 27 figures, appendices, July-September 1957. (C)

Squib aging for 67 weeks in an ammonia atmosphere or in an oven at 160°F. Storage of T13E1 engines at either 160°F for 6 to 12 months or under igloo conditions for 30 to 36 months to study environment effects on ignition.

D. 7. 9 R. P. King et al., "Investigation of Ignition Systems for Polysulfide-Perchlorate Propellant Rocket Engines," Report No. 38-58, Thiokol Chemical Corp., Redstone Arsenal, Redstone, Alabama, April 1955-March 1957.

Two aging studies are being performed on five new engines.

D. 7. 10 F. James, "A Brief Review of British Work on the Ignition of Solid Propellants in Rockets," SPIA, JANAF Second Ignition Symposium, vol. II, (Armament Research and Development Establishment, United Kingdom) October 1956. (C)

Summarizes briefly all British work on rocket ignition with more special mention of early work, reports of which are not now available.

D. 7. 11 G. W. Peet, et al., "Improved Initiators for Rocket Igniters," SPIA, JANAF Second Ignition Symposium, vol. II, p. 87, Naval Ordnance Laboratory, October 1956. (C)

Presents studies on the feasibility of improving standard rocket ignition systems. The XG-9B1 composition also will withstand 2 weeks JAN cycle surveillance and severe aircraft vibration without deterioration.

D. 7. 12 J. E. Pelham, "Description of Jelly-Roll and Related Type Ignition Systems," SPIA, JANAF Second Ignition Symposium, vol. II, p. 29, Thiokol Chemical Corp., Redstone Arsenal, Redstone, Alabama, October 1956. (C)

Presents a description of the jelly-roll igniter and subsequent igniter designs evolved from the same principle.

D.7 IGNITION SYSTEMS (Continued)

D.7.13 G.J. Bryan and E.K. Lawrence, "Application of Fundamental Data to Gun and Rocket Ignition," SPIA, JANAF Second Ignition Symposium, U.S. Naval Ordnance Laboratory, vol. I, p. 1, October 1956. (C)

Basic ignition information has been applied to correlating ignition data from a large number of guns and rockets: guns ranging in caliber from 20 mm to 16 inches, and rockets ranging in internal exposed area from 145 to 320,000 cm^2.

D.7.14 "Quarterly Progress Report (Composite Propellant Rocket Development)" Report No. 1-57, Thiokol Chemical Corp., Redstone Arsenal, Redstone, Alabama, 123 pp., 33 tables, 92 figures, October-December. (C)

Squib Development: The du Pont S-89 and X-258B, U.S. Flare 107-A, and McCormick-Selph 1204-A squibs were fired after 16, 20, 24, and 30-week aging; RAS-1-3 was added to the aging program.

Squib Development: 4 types of squibs were fired after 16, 20, 24 and 30-week aging.

D.7.15 L.A. Dickinson, "Igniter Compositions in Relation to Canadian Igniter Practice," SPIA, JANAF Second Ignition Symposium, Canadian Armament Research and Development Establishment, vol. I, p. 303, October 1956. (C)

Evaluates application of various ignition compositions to motor systems and results obtained, in an effort to elucidate shortcomings and advantages of present compositions.

D.7.16 D.C. Vest, "The Status of Studies on Elmite-Extruded Igniter Materials," SPIA, JANAF Second Ignition Symposium, Ballistic Research Laboratory, Aberdeen Proving Ground, Aberdeen, Maryland, vol. I, p. 327, October 1956. (C)

Evaluate Elmite, a family of extruded igniter materials whose properties suggest that it might suitably replace black powder in ignition systems.

D.7.17 H.M. Platzek, "Propellant Ignition Studies Being Conducted With New Igniter Materials," SPIA, JANAF Second Ignition Symposium, Naval Ordnance Test Station, China Lake, California, vol. I, p. 353, October 1956. (C)

Evaluates standard and new igniter materials.

D. 7 IGNITION SYSTEMS (Continued)

D. 7. 18 J.I. Bujes, "Testing Rocket Fuzes for Armed Condition," NOTS 1548 NAVORD 5312, Naval Ordnance Test Station, China Lake, California, 15 pp. 8 figures, 17 September 1956.

Describes method for determining the armed or unarmed conditions of Mk 190 Mod 0 fuzes by application of X-rays or gamma rays.

D. 7. 19 C.H. Anderson, "Evaluation of Preliminary Lots of Igniter Mk 125 Mod 4 Manufactured by Federal Ordnance, Inc.," NOTS 1570 NAVORD 5323, Naval Ordnance Test Station, China Lake, California, 16 pp, 6 tables, 12 September 1956. (C)

U. S. Naval Ordnance Test Station evaluated two 500-unit preliminary lots of the Igniter Mk 125 Mod 4, manufactured by Federal Ordnance, Inc., in accordance with Mil. Spec. MIL-I-17943. Both lots were rejected.

D. 7. 20 "Igniter Improvement," Thiokol Chemical Corp., Redstone Arsenal, Redstone, Alabama, PR Nos. 1-56, 10-56, 21-56 and 33-56 (October 1955 - September 1956). (C)

Squib development: evaluation of new igniter mixtures.

D. 7. 21 K.J. Korpi, "Survey of Ignition Literature," Contract No. AF33(616)-3072, Report No. 1097 (Special), Aerojet General Corporation, Azusa, California, 69 pp., 10 July 1956. (C)

Survey of ignition literature: review of work done by major agencies involved in solid propellant ignition. Ignition research included design of igniters, development of various compositions, theoretical and experimental investigations of ignition phenomena, and modes of energy transfer.

D. 7. 22 J.E. Pelham and R.P. King, "Development of a Reduced-Debris Igniter System for Small Air-to-Air Rockets," (Final Report), Report No. 3-56, Thiokol Chemical Corp., Redstone Arsenal, Redstone, Alabama, 23 pp., 22 figures, 8 tables, March 1956. (C)

Ignition malfunctions occured after 2 weeks of storage at 160°F at low-debris igniters.

D. 7. 23 "Service Test of Fuze, VT M504A2, After Exposure to the Weather Under Simulated Combat Conditions," Project AA4531254, AD366559, Continental Army Command, Fort Bliss, Texas, 5 October 1955.

D.7 IGNITION SYSTEMS (Continued)

D.7.24 J.E. Pelham, "Investigations of Ignition Systems for Polysulfide-Perchlorate Propellant Rocket Motors," PR No. 34-55, Thiokol Chemical Corp., Redstone Arsenal, Redstone, Alabama, 47 pp., 15 tables, 13 figures, September 1955.

Squibs were subjected to ammonia atmosphere at extreme temperatures for up to 2 years. Copper shields deteriorated while aluminum shields held up. Igniter improvements were made.

(See References C.54 and D.18.53.)

D. 8 INHIBITORS/LINERS

D. 8. 1 J. Cohen, et al., "Research and Development of Solid Propellants for Large High-Performance Rockets," Report No. 1314-4, Aerojet-General Corporation, Azusa, California, (Quarterly), 85 pp., 14 tables, 28 figures, June-August 1957. (C)

Studies SD-716 and SD-721 liner aging at 180°F.

D. 8. 2 "Development of Composite Propellant Booster Unit," Report No. 726-4-57RF, Phillips Petroleum Company, McGregor, Texas, 9 pp., August-October 1957. (C)

Accelerated aging study of the R-107/A-102 restrictor-adhesive system for a 1-year period.

D. 8. 3 "Development of Solid Propellants for Use in Large Rocket Engines," Thiokol Chemical Corp., Elkton Division, Elkton. Maryland, QPR Nos. 2 and 3, 98 pp., 43 tables, and 63 figures, appendices, April-September 1957.

Improved liner investigations including 2-month aging at 120°F and short-term storage at 270°F.

D. 8. 4 "Cast Double-Base Propellant and JATO Development," Allegany Ballistics Laboratory, ABL/MPR 65, (15 January-15 February 1957), 101 pp., 29 tables, 35 figures, 1 March 1957. (C)

Case Bonding (17102A): Effects of storage of precoated chambers on the bonding properties of the case-bonding adhesive.

D. 8. 5 R. T. Nagler, "Ballistic Stability of Ball Powder Under High Temperature Storage," Technical Report No. 149, Badger Ordnance Works, 8 pp., 11 June 1956.

Study of effects of elevated temperature (125-150°F.) storage on ball powder. Studies indicate migration of NG, volatiles, or combinations of these.

D. 8. 6 D. V. Clifford, "Polyester Resins for the Inhibition of the Burning Surfaces of Colloidal Propellants," Technical Memorandum No. 3/M/55, (British), Explosives Research and Development Establishment, Waltham Abby, United Kingdom, 31 pp., 16 tables, 4 figures, January 1956. (C)

Describes methods for casting inhibiting coatings to prevent NG migration, using commercially available polyester resins. Various difficulties encountered due to temperature cycling or migration of NG are reported.

D. 8 INHIBITORS/LINERS (Continued)

D. 8. 7 E. L. Moon, "Use of Scale Models in Surveillance Testing for Plasticizer Migration in Rocket Grains," NOTS 1282 NAVORD 4960, Naval Ordnance Test Station, China Lake, California, 31 pp., 8 tables, 8 figures, 11 November 1955.

Scale model surveillance testing of plasticizer migration in rocket grains was investigated, then compared to results obtained with full-scle GIMLET grains.

D. 8. 8 G. W. Harding, et al., "The Effect of a Nitroglycerine/Triacetin Mixture on Natural and Synthetic Rubbers," Report No. DMXRD RU/55/3, Directorate of Materials and Explosives, 66 pp., 4 tables, 1 figure, September 1955. (C)

Samples of natural rubber, acrylonitrile rubber, acrylo-polychloroprene, butyl rubber, and polythene were immersed in a mixture of NG and triacetin at 70°C for intervals up to 60 days. Acrylonitrile rubber suffered the most severe swelling and deterioration. The mixture was a typical casting liquid used in preparing cast double-base propellants.

D. 8. 9 J. M. Hannigan, "Research and Development on Inhibiting Methods," Summary Report on Contract NORD 12320, Universal Match Corporation, December 1951 through June 1954. (C)

An extended study of the migration of NG and plasticizer through inhibited grains and their coatings.

D. 8. 10 G. C. Whitnack and E. St. Clair G[illegible]z, "Polargraphic Determination of Nitroglycerin and Phth[illegible]te Esters in Plastics and Double-Base Powder," NOTS 674 [illegible]VORD 2019, Naval Ordnance Test Station, China Lake, [illegible]ifornia, 10 pp., 4 tables, 23 March 1953.

Describes a polargraphic met[illegible] of analysis for determining the migration of nitro[illegible]erine and inert plasticizer from the powder t[illegible] the plastic inhibitor, and from the inhibitor to the p[illegible]wder in accelerated-aging tests on small samples of the inhibited powder.

D. 8. 11 D. D. Ordahl, "The Development of a Test for the Evaluation of the Bond Between Inhibitors and Propellant Grains," TM419, Naval Ordnance Test Station, China Lake, California, 34 pp., 14 figures, 9 tables, 13 March 1951. (C)

Test developed for evaluating the quality of the bond between the propellant and inhibitor on finished grains from normal production.

D.9 ORDNANCE DEVICES

D.9.1 L.M. Singer, "Investigation of Failure to Function of Solid Propellant Gas Generator for Atlas Missile," (U), Report No. 00Y-TR-65-5555, AD-362969 X65-20561, Ogden Air Materiel Area, Hill AFB, Ogden, Utah, June 1965. (C)

D.9.2 L.M. Singer, "Evaluation of Atlas Solid Propellant Gas Generators with Defective Propellant Grains," Report No. 00Y-TR-65-110-G, Ogden Air Materiel Area, Hill AFB, Ogden, Utah, May 1965.

Solid propellant gas generators removed from field sites and radiographically inspected at Ogden Air Materiel Area for cracks or other propellant imperfections were sent to Edwards Air Force Base for qualification testing of reworked engines. During inspections, several solid propellant gas generators were rejected because their grains appeared to have cracked propellants. This test was established to investigate the probability that cracked grains may cause the solid propellant gas generators to operate out of design specification or possibly cause overpressurization and explode when functioned.

First article performance tests on solid propellant gas generator initiators, ORDCO P/N B5750, were incorporated in this project. One initiator was installed in each solid propellant gas generator.

In the first test, the pressure-time data was lost on a booster solid propellant gas generator due to instrumentation failure. Two other sustainer solid propellant gas generators tested produced pressures which were above maximum specification limits.

D.9.3 L.M. Singer, "Serviceability and Leak Tests on Atlas Vernier Engine Igniters," Report No. 00Y-TR-64-816, AD451089, X65-12086, Ogden Air Materiel Area, Hill AFB, Ogden, Utah, October 1964.

D.9.4 G.H. Kawonishi, "Service Life Test of Atlas Retrorocket Motor P.N D-20550 (U), Report No. 00Y-TR-64-751, AD 353669, X65-11261, Ogden Air Materiel Area, Hill AFB, Ogden, Utah, September 1964.

D.10 O-RINGS/SEALS

D.10.1 "R.M.A. Long-Term O-Ring Shelf Aging Tests, Data Report," Rubber Manufacturers' Association, 444 Madison Avenue, New York, New York, 1 March 1966.

In 1956 the Rubber Manufacturers' Association, O-Ring Division, decided to test the validity of age controls specifications. Seven laboratories of member companies stored particular lots of rings of a variety of compounds and at intervals drew samples from these lots for test. Materials tested include MIL-P-5516, commercial Nitrile, commercial Neoprene and Butyl rubber. In several cases, individually packaged O-rings were included. No significant improvement in shelf aging characteristics is noted for packaged rings. This report includes data up to 32 quarters or approximately 8 years of shelf aging.

D.10.2 R.E. Cierniak, et al, "Study of O-Ring Aging Characteristics," R 5990, AD 468103, IDEP 345.50.00.00-G1-02, Rocketdyne Division, North American Aviation Co., Canoga Park, California, 30 December 1965.

Results of an investigation of the aging characteristics of elastomers and compliant materials used in liquid rocket engines.

D.10.3 I. Lade, "Reliability of Seals, Valves, Pumps, Bearings, Tubes, Gas Turbines, and Pressure Vessels; A List of Journal and Document References," AD 460041, X65-16669, IDEP 347.10.00.00-A6-02, Aerojet-General Corp., Sacramento Plant, Technical Library, 2 July 1964.

Includes references from 1959 to 1964.

D.10.4 "Study of Physical Properties Necessary for Satisfactory Functioning of an O-Ring," R-5290, AD 468042, IDEP 345.50.00-G1-01, Rocketdyne Division, North American Aviation Co., Canoga Park, California, 15 August 1963.

Laboratory studies to establish functionally significant physical properties of O-rings in aging.

D.10.5 "Study of O-Ring Aging Characteristics," Final Report No. R-5253, AD426505, Rocketdyne Division, North American Aviation Co., Canoga Park, California, 15 August 1963.

Results of an investigation of synthetic elastomer age deterioration to provide information on service life estimates of liquid rocket engines.

D. 10 O-RINGS/SEALS (Continued)

D. 10. 6 R. R. Mortensen, et al, "Aging of Cure-Dated Items and Various Elastomeric Compounds," Report No. AD 282-230, Oklahoma University Research Institute, Normal, Oklahoma, 31 January 1962.

Discusses correlation between natural and accelerated aging and chemical properties, swelling, and leaching of constituents from O-rings; mentions radiation and temperature retraction.

D. 10. 7 "Design Handbook for O-Rings and Similar Elastic Seals," Boeing Airplane Co., for Wright Air Development Center, Wright-Patterson AFB, Dayton, Ohio.

WADC TR 59-428, F. W. Tipton, October 1959, AD 230639.

WADC TR 59-428, Part II, W. R. Walker, April 1961, AD 265443.

Handbooks published as a conclusion of the effect reported in D. 10. 11. Covers the mechanism of O-ring sealing, relationship between physical properties and sealing, cavity configuration, and seal life, as well as aging and procedures for controlling aging with relation to storage. Also includes bibliography.

D. 10. 8 D. V. Steel and A. R. Timmins, "O-Ring Material for Naval Ordnance Applications," NAVWEPS Report 7284, AD248647, Chemistry Research Department, U.S. Naval Ordnance Laboratory, White Oak, Maryland, 1 August 1960.

MIL-P-5516 and silicone O-rings were evaluated for use in pneumatic service in a rotary Safe-Arm (SA) device. Reported and concluded are tables of qualification test values, outdoor and accelerated aging and ozone tests, lubricant compatibility tests which accepted DC55 but rejected DC-4, low temperature evaluation tests, and 18-month storage in the SA device which showed the need for lubrication of the rings as a protection from ozone attack.

D. 10. 9 J. I. Bujes and D. C. Harms, "Detection of O-Ring on Igniter Cap of 2.0-inch GIMLET Rocket Motor," Report No. NOTS 1440 NAVORD 5241, Naval Ordnance Test Station, China Lake, California, 13 pp., 7 figures, 23 April 1956.

Describes a method of detecting O-rings in assembled rocket motors. The inspection was developed for rejecting defective motors from a conveyor line.

D.10 O-RINGS/SEALS (Continued)

D.10.10 G.E. Trepus, et al., "Design Data for O-Rings and Similar Elastic Seals," Boeing Airplane Company for Wright Air Development Center, Wright-Patterson Air Force Base, Dayton, Ohio.

D-17416-1, 15 January 1956, AD 094-749
Progress Report, 15 October 1955-15 January 1956.

WADC TR 56-272, Part I, May 1956 AD 110-598
Progress Report, January-May 1956.

WADC TR 56-272, Part II, September 1956, AD 131094
Progress Report, May 1965-March 1957.

WADC TR 56-272, Part III, April 1958, AD 151181,
Progress Report, June-December 1957.

WADC TR 56-272, Part IV, July 1959
Progress Report, January-June 1959.

WADC TR 56-272, Part V, March 1960, AD 237330
Progress Report, July-December 1959.

WADC TR 56-272, Part VI, May 1961, AD 267501
Progress Report, February-December 1960.

Reports of a study to obtain and develop seal design information for preparation of a handbook. Includes literature surveys, seal properties, and attempted correlation on aging and storage of seals and seals for extreme environment, as well as functional and failure mechanisms for seals.

D.10.11 B.J. Clinebell, "O-Rings, An Annotated Bibliography," India Rubber World, vol. 7, pp. 74-78, October 1952.

D.10.12 J.M. Halloway and R.E. Norris, "Effect of Shelf Aging on MIL-P-5516A O-Rings," Mare Island Naval Shipyard, Vallejo, California.

Report No. 92-6, Progress Report No. 1, 29 February 1960

Report No. 92-7, Progress Report No. 2, 26 January 1961

Report No. 92-9, Progress Report No. 3, 8 February 1962

Report No. 92-15, Progress Report No. 4, 29 January 1963

MIL-P-5516A O-rings from two suppliers were tested after 4 years shelf life and periodically for the next 4 years. No significant change has been noted in the physical properties measured.

D.10.13 T.C. Goodwin, "O-Rings, A DDC Bibliography," Report No. AD 422417, Defense Documentation Center, Cameron Station, Alexandria, Virginia.

D.10 O-RINGS/SEALS (Continued)

Seals

D.10.14 "Development of an Elastomeric Seal for Omniaxial Movable Nozzles (Lockseal), Progress Report No. 2," LPC 689-Q-2, AFRPL-TR-65-173, Lockheed Propulsion Company, Redlands, California, August 1965. (C)

Describes failure analyses of "buckling" under compressive loads, includes unbonding of rubber pad from reinforcement.

D.10.15 J.M. Manger, "Sealed Storage of Concentrated Hydrogen Peroxide," APL Bulletin of 7th Liquid Propulsion Symposium, vol. I, AD 365467, Seal Division, August 1965.

D.10.16 P. Bauer, et al., "Analytical Techniques for the Design of Seals for Use in Rocket Propulsion Systems," AF RPL-TR-65-61, vol. 1, Static Seals AD 464958, vol. II, Dynamic Seals, AD 464959, ITT Research Institute for Air Force Rocket Propulsion Laboratory, Edwards AFB, California, Ma 1965.

port on investigations conducted to develop analytical design techniques for static, sliding, and rotating shaft seals as applied to rocket propulsion systems.

D.10.17 R.L. George and R.C. Elwell, "Study of Dynamic and Static Seals for Liquid Rocket Engines," Volume I, Description of Program and Review of Presently Available Sealing Methods, CR-50663, N63-19595, Volume 2, Studies of Special Topics in Sealing, CR-50662, N 63-19498; Volume 3A, Bibliography of ASTIA Literature on Seals, CR-50661, N 63-19596; Volume 3B, Bibliography of Open Literature on Seals, CR-50660, N63-19597, Advanced Technology Laboratories, General Electric Company, Schenectady, New York, 25 February 1963.

D.10.18 S.L. Bust, et al., "Aging of Installed Rubber and Plastic Gaskets in Simulated Flight Hardware," Report N64-17607, George C. Marshall Space Flight Center, Huntsville, Alabama, 5 March 1962.

D.10.19 J.H. Pemm, J.J. Petersen, "Physical Properties of Some Engineering Materials, Unpublished Data from Company Sponsored Programs," Quarterly Report No. 3, Vol 1, on Phase I, September-November 1961, Report No. AER-EIR-354, AD 268-381, Chance Vought Corporation, Dallas, Texas, 15 December 1961.

D. 10 O-RINGS/SEALS (Continued)

D. 10. 20 H. C. Hunnel and R. W. Conover, "Laboratory Performance Tests of Standard and Experimental O-Rings as Rocket Motor Seals," Summary Report July 1954 to January 1958, NOTS 2062, NAVORD Report No. 6380, AD 205587L, Naval Ordnance Test Station, China Lake, California, 11 August 1958.

O-Rings of various formulations and shapes were tested and evaluated. Performance test developed as reported in NAVORD Report 3401, NOTS 988, are affirmed for use as a basis for specifying rocket motor O-Ring seals.

D. 10. 21 T.H. Schafer, "Preliminary Study of O-Ring Life," Report No. ZX-8-006, IDEP 345.90.25.75-D6-01, 10 July 1957.

The life of O-ring seals was measured under different test conditions exploring the influence of surface finish, squeeze, clearance, lubrication, rubbing speed, rate of pressure variations, and temperature.

D. 10. 22 J.A. Neigel, K.F. Peter and H.E. Heigis, "A Summation of the Pneumatic High Temperature Seal Evaluation Program as conducted by Walter Kidde and Company," Walter Kidde Company, Belleville, New Jersey, 12 June 1956.

A general survey of the work of Walter Kidde in evaluating O-rings and lubricants for high pressure pneumatic systems (3000 psi 225°F). Contains many fundamental principles on O-ring mechanism of operations and failure in this service together with a summary of test results screening materials, lubricants, and seal types and shapes.

D. 10. 23 S.A. Eller, "Stress Relaxation Versus Sealability of MIL-R-900 Gasket Materials," Rubber Age, vol. 79, no. 3, pp. 455-458, June 1956.

Investigation to determine the relationship between stress relaxation and seal aging properties of elastomer gasket materials.

D. 10. 24 R.J. Berg, "A Review of Seal Materials for Guided Missile Applications," Progress Report 20-340, AD 163-020, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, 7 March 1956.

A survey was made of polyethylene, Teflon, Kel-F, nylon, polyvinyls, GRS, natural rubber, Buna-N, silicone, neoprene, butyl rubber, and hypalon to select those most usable for present and future needs. Laboratory tests were developed to evaluate new seal materials. Tests are given which are intended to guide the selection of O-ring seal materials.

D. 10 O-RINGS/SEALS (Continued)

D. 10.25 "The Design of O-Ring Seals for Rockets," NOTS Technical Memo No. 1046, AD82-306, American Designers, Inc., 17 March 1952.

D. 10.26 D.E. Gerberich, et al., "Experimental Investigations of Optimum Enclosure for "O" Sections Synthetic Rubber Seal Ring," WADC Technical Report No. 53-319, July 1951-December 1952, AD27-728, August 1953.

Nine types of enclosures were tested for static sealing by using artificially aged rings to simulate conditions after extended service.

D. 10.27 T.A. Werkenthin, et al., "Sealing and Seal-Aging Properties of Rubber Gaskets," Rubber Age, vol. 56, no. 4, pp. 389-96, January 1945.

Investigation of medium soft natural and synthetic rubber gaskets for various types of closures including the test methods for evaluating sealing capability and material properties.

D.11 PLASTICS/INSULATION

D.11.1 "Teflon, A Report Bibliography," Report No. AD 467800, Defense Documentation Center, Cameron Station, Alexandria, Virginia, 6 August 1965.

D.11.2 N. T. Boldanzer, "A Review of Non-Destructive Testing for Plastics: Methods and Applications," Report No. PLASTEC-22, AD472712, Plastics Technical Evaluation Center, Picatinny Arsenal, Dover, New Jersey, August 1965.

D.11.3 K. J. Ledbury, "Accelerated Aging of Plastics, Part 1, Degradation of Thermoplastics Materials Under Dry and Humid/Hot Conditions," Report No. ERDE-181 M/64, WAC/157/017, X65-18674, Explosives Research and Development Establishment, Waltham Abbey, England, 27 June 1965.

D.11.4 E. Ledbury and A. L. Stokoe, "Accel Aging of Plastics, Part 2, Degradation of Thermoplastics in Contact with Explosives," Report No. ERDE-7/M/65, AD 467771, Explosive Research and Development Establishment, Waltham Abbey, England, 19 April 1965.

Deterioration of various plastics in contact with TNT and RDX/TNT and propellants NG and NQ was measured by changes in tensile strength, elongation, and weight.

D.11.5 J. Scheffer, "The Aging of Plastics by Atmospheric and Microbiological Corrosion (Ueroudering Van Kunststoffendoor Atmosfrische en Microbiologishe Aantasting)," bibliography in Dutch and English, Report No. CDCK-41135, AD 464711, X65-18807, January 1965.

D.11.6 "Stress Cracking of Plastics," An Annotated and Indexed Bibliography," a comprehensive bibliography on stress cracking of plastics including descriptions as well as author and subject index.

1. PDC Search No. 64-026-3, AD 446424, 29 abstracts, August 1964.
2. PDC Search No. 64-026-3, AD 446425 August 1964.
3. PDC Search No. 65-025-3, PDL-51940, AD 460482, 33 abstracts included in this installment, 15 February 1965.

D.11.7 R. A. Sato, "Teflon Burst Diaphragm Leak Test," Report No. AD 298516, Aerojet-General Corporation, Sacramento, California, October 1962.

Leak test of a teflon burst diaphragm for the Titan II Start Cartridge.

D. 11 PLASTICS/INSULATION (Continued)

D. 11. 8 G. Liebling S. Barton, and R. Ullman, "Effect of Radiation of Polyethylene on Environmental Stress Cracking," Journal of Applied Polymer Sciences, pp. 461-464, July-August 1962.

Irradiation of polyethylene with cobalt-60 rays reduces or eliminates stress cracking if the sample is heated under vacuum before exposure to air. Apparently the trapped radicals in the solid polymer combine with each other on heat treatment; when exposed to air without heating these radicals react with the oxygen. The oxidized material becomes brittle and crumbles.

D. 11. 9 "Transactions of the 6th Symposium on Ballistic Missile and Aerospace Technology, 28-30 August 1961, vol. III, Design, Operations and Reliability," Aerospace Corp., El Segundo, (AFBMD), California, 404 pp.

D. 11. 10 A. O. Kays, et al., "Behavior of Materials Under [illegible] Conditions," Thiokol Chemical Corp., Redstone Div., Huntsville, Alabama. (C)

Discusses reinforced plastics, elastomers, ceramics, refractory metals and alloys, and combinations thereof. Provides criteria for selection of materials for specific applications.

D. 11. 11 D. L. Chamberlain, Jr., "Effect of Radiation on the Mechanical Properties of Plastics," Final Report on SRI Project No. Su-2296, Stanford Research Institute, Menlo Park, California, 19 February 1960.

D. 11. 12 W. A. Dukes, "Predicting the Endurance of Pressurized Polyethylene Pipe," Brit. Plastics, 33, pp. 575-7, 1960.

D. 11. 13 K. Richard, et al., "Creep Rupture Strength of Plastic Pipes Poly (Vinyl chloride)(PVC) and Ziegler-Polyethylene Pipe Materials," Kunstoffe 49, pp. 616-21, 1959.

D. 11. 14 K. T. Carolan and M. Chumura, "Storage Stability of Cellulose Nitrate Plastics," Technical Report 2440, AD 137856, U.S. Picatinny Arsenal, Dover, New Jersey, 22 pp., July 1957.

Standard tensile specimens of cellulose nitrate plastics were exposed (1) outdoors at Picatinny Arsenal, New Jersey; Fort Churchill, Canada; White Sands, New Mexico; and Panama for 3 years; (2) in the dark at 77°F and 50 percent for 3 years; (3) in the dark at 160°F for 2 years; and (4) to sunlight for periods from 1 day to 1 month, then to darkness at 160°F up to 3 months.

D. 11 PLASTICS/INSULATION (Continued)

D. 11. 15 W.P. Whelan, "Improved Insulators for Rocket Motors," (U), (Quarterly Progress Report, March-May 1965), Report No. APR-0153-7, AD 362878, X65-19443-, U.S. Rubber Company, Wayne, New Jersey; (also 1 September-30 November 1965, P. Viohl, 4 January 1965, QPR-5, AD 357220), June 1965. (C)

D. 11. 16 "Space Environment Effects on Polymeric Materials," Stanford Research Institute, Interim Technical Report No. 2, JPL Contract No. 950324 under Contract NAS 7-100, 30 May 1965.

D. 11. 17 J.S. Whittic' Effects of Spacecraft Environments on Polymeric Materials," Stanford Research Institute, Special Bibliography, JPL Contract No. 950324 under Contract NAS 7-100, 15 January 1965.

D. 11. 18 C. Toscano and V.F. Hribar, "A Critique of Internal Insulation Materials for Solid Propellant Rocket Motors and Their Effect on Missile Performance," SSD-TDI 64-266, AD 45?371, X65-14178, Aerospace Corpora El Segundo, California, 15 January 1965.

Concerns the effects of case internal insulation on missile performance and the technology of current and advanced insulation materials; also contains information on the location of internal insulation in the typical solid propellant rocket motor and the aerothermodynamic environment at selected locations. Presents a survey of current and advanced elastomeric type internal insulation materials. Includes a brief description of the various test methods used for evaluating current and advanced materials. Recommendations are made for future development effort of advanced internal insulation materials.

D. 11. 19 D.L. Abend, "Athena Vehicle Insulation Property Evaluation of Insulating Materials Test," 220-TR-013, AD 459331, IDEP 565-40.00.00-AR-01, Atlantic Research Corporation, Duarte, California, 5 June 1964.

Test determined a time-temperature history at different points along the surface of the X-261 inert motor while subjected to actual environmental conditions, and established a confidence level for predicted hold-time versus ambient temperatures for both the X-261 and X-259 motors by direct comparison between actual test data and analytical results based upon the same environmental conditions. Test articles used were an inert X-261 second stage motor, 2755 Armstrong Cork, and rigid urethane board stock No. CPR-9002, Thermal Insulation Material.

D. 11 PLASTICS/INSULATION (Continued)

D. 11. 20 "Thermal Degradation of Polymers," Society of Chemical Industry, S.C.I. Monograph No. 13, London, 1961.

D. 11. 21 A. V. Tobolsky, Properties and Structure of Polymers, John Wiley and Sons, Inc., New York, 1960.

D. 11. 22 J.F. Brown, et al., "Heat and Erosion Resistance on Materials-Insulation, Thermal," Report No. AD 286475, General Dynamics, Pomona, California, February 1959.

Insulating composites were subjected to heated air impingement simulating Mach 3.2 equivalent surface temperature and 52, 500-foot altitude pressure. Report includes evaluation of fluroelastomeric rubber, Teflon-impregnated fiberglass, silastic rubber-fiberglass, and cork.

D. 11. 23 N. Grassie, Chemistry of High Polymer Degradation Processes, Butterworths Scientific Publications, London, 1956.

D. 11. 24 H.R. Conrad, "Insulation Studies," MPR 51, Allegany Ballistics Laboratory, Cumberland, Maryland, 2 pp., 2 figures, 1 January 1956. (C)

British rubber insulation (B-102) bonded with plibond to an X223 chamber with OIY propellant withstood 6 months of storage at 120°F without discernable deterioration.

D. 12 PROPELLANTS

D. 12. 1 N. Fishman, "Environmental Effects on Solid Propellants," Solid Rocket Structural Integrity Abstracts, vol. III, no. 1, 1966.

D. 12. 2 S. J. Bennett, and G. P. Anderson, "Mechanical and Failure Propertiesof Propellant in a Multiaxial Stress Field," Bulletin of 4th Meeting ICRPG Working Group on Mechanical Behavior, vol. 1, November 1965.

D. 12. 3 P. C. Colodny, and G. F. Ketchum, "Humidity and Temperature Effects on the Creep Behavior of Solid Propellants," Bulletin of 4th Meeting ICRPG Working Group on Mechanical Behavior, vol. 1, November 1965.

D. 12. 4 W. D. Hutchinson, G. W. Becker, and R. F. Landel, "Determination of the Stored Energy Function of Rubber-Like Materials," Bulletin of 4th Meeting ICRPG Working Group on Mechanical Behavior, vol. 1, November 1965.

D. 12. 5 M. Sharma, "Dynamic Compressibility Measurements of an Inert Composite Propellant at Low Frequencies," Bulletin of the 4th Meeting ICRPG Working Group on Mechanical Behavior, vol. 1, November 1965.

D. 12. 6 A. San Miguel, "On the Characterization of Multiaxial Data in Terms of the Strain Energy Concept," Bulletin of the 4th Meeting ICRPG Working Group on Mechanical Behavior, vol. 1, November 1965.

D. 12. 7 C. Robinson, and P. Graham, "Dynamic Mechanical Properties of Solid Propellants and Propellant Binders," Bulletin of the 4th Meeting ICRPG Working Group on Mechanical Behavior, vol. 1, November 1965.

D. 12. 8 B. [illegible]arbert, "Triaxial Testing of Solid Propellants," Bull[illegible] of the 4th Meeting ICRPG Work[illegible] Group on Mechanical Behavior, vol. 1, November 1[illegible]6[illegible]

D. 12. 9 D. Cantey, "An App[illegible]ratus [illegible] Measurement of Dynamic Effec[illegible] in Rheological Mat[illegible]ials," [illegible]ulletin of the 4th Meeting ICRPG Working Group on Mechani[illegible] [illegible]or, vol. 1, N[illegible]ember 19[illegible]

D. 12. 10 B. Gilmour, "[illegible]diation Effects on Propellants and Ex[illegible]ves: An Annotated Bibliography," Battelle Memorial Institute, REIC Memorandum 28, 29 October 1965.

D. 12. 11 L. Danziger, et al., "Monitoring Internal Stresses in Solid-Propellant Motors," Report No. NPP-TMR-232, Task 71401, U.S. Naval Propellant Plant, Indian Head, Maryl[illegible]d, 20 October 1965.

Describes embedding miniature pressure transducers in a motor to determine stress changes.

D. 12.13 P. Colodny, and G. Ketchum, "Humidity and Temperature Effects on the Group Behavior of Solid Propellants," Bulletin of the 4th Meeting of the ICRPG Working Group on Mechanical Behavior, CPIA Publication No. 94U, pp. 135-140, October 1965.

D. 12.14 H. Edgington and B. Leibel, "A Non-Destructive Testing Technique for Monitoring Solid Propellant Aging," Report No. 3071, Aerojet-General Corp., Azusa, California, 7-July, 15 August, September 1965. (C)

Utilizes electrical properties of propellant to detect changes with age.

D. 12.15 A. Messner, and D. Schliessmann, "Transient Thermal Stresses in Solid Propellant Grains," J. Spacecraft and Rockets, vol. 2, pp. 565-570, July-August 1965.

D. 12.16 K. Bills, Jr., H. Fong, et al., "Rational Estimation of the Useful Life of Solid Propellants," Presentation at ICRPG Meeting, San Francisco, California, June 1965.

D. 12.17 N. Garman and J. Murphy, "Long Range Study of Prediction of Safe Life of Propellants," Technical Memorandum 1609, Picatinny Arsenal, Dover, New Jersey, 92 pp, April 1965.

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D [illegible] R. Schapery, "Thermomechanical Response Studies of Solid [illegible]ants Subjected to Cyclic and Random Loading," AIAA [illegible] 65-160, presented at the AIAA 6th Solid Propellant [illegible]ence, 1-3 February 1965.

D [illegible]n, and J. Rinde, "Solid Propellant Mechanical [illegible] Investigations," Stanford Research Institute Final Repor[illegible]ontract AF 04(611)-9559, 2 December 1964.

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D. 12.22 G.H. Lindsay, "Stress Distributions in a Poker Chip Specimen Subject to Combined Loads," Bulletin of 3rd Meeting ICRPG Working Group on Mechanical Behavior, vol. 1, November 1964.

D. 12.23 A. San Miguel, and R.H. Silver, "Radial Stress Measurement in Propellant Grains," Bulletin of 3rd Meeting ICRPG Working Group on Mechanical Behavior, vol. 1, November 1964.

D.12.24 J. Stoker, "The Effects of Fatigue Loading Upon Solid Propellant," Bulletin of the 3rd Meeting of the ICRPG Working Group on Mechanical Behavior, CPIA Publication No. 61U, pp. 421-436, October 1964.

D.12.25 "Propellant Storability in Space," Technical Documentary Report No. RPL-TDR-64-75, General Electric Co., Spacecraft Department, P.O. Box 8555, Philadelphia, Pennsylvania, June 1964.

Results and interpretation of tests are presented for storability of propellants in space.

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D.12.27 J. Majerus, and M. Tamekuni, "The Effect of Material Nonlinearity and Failure Criteria upon Predicted Propellant Grain Reliability," Aerojet-General Corp., SRO Report, 1964.

D.12.28 R. Davis and A. Abston, "Results of Three Years of Aging of TP-H8041 Propellant," (Special Report) Report No. C-63-430A, Thiokol Corp., Alpha Division, Huntsville, Alabama, 25 November 1963. (C)

D.12.29 R. Markle, et al., "Evaluation of Solid Propellants Stored in Simulated Space Environment," Bulletin of the Second Meeting, ICRPG Working Group on Mechanical Behavior, pp. 161-179, November 1963.

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D.12.30 K. Bischel, and R. Feist, "Thermal Strains in Cylindrical Solid Propellant Motors," Bulletin of the Second Meeting of the ICRPG Working Group on Mechanical Behavior, CPIA Publication No. 27, pp. 299-307, October 1963.

D.12.31 N. Fishman and J. Rinde, "Dilatation of Composite Propellants," Bulletin of the Second Meeting of the ICRPG Working Group on Mechanical Behavior, October 1963.

D.12.32 J. Hutchinson, "Stresses in Solid Propellants Due to High Axial Acceleration," AIAA Journal, vol. 1, pp. 2410-2412, October 1963.

D.12.33 A. San Miguel, and E. Duran, "Some Experiments and Theoretical Significances Associated with Irradiated Propellant," Bulletin of the Second Meeting of the ICRPG Working Group on Mechanical Behavior, CPIA Publication No. 27, pp. 257-272, October 1963.

D. 12. 34 R. Spangler, "A Biaxial Stress Strain Tester for Solid Rocket Propellants," Bulletin of Second Meeting ICRPG Working Group on Mechanical Behavior, October 1963.

D. 12. 35 K. Bills, and J. Wegard, "Relation of Mechanical Properties to Solid Motor Failure," AIAA Journal 1:2116-23, September 1963; also see Rubber Chemistry & Technology, 37:524-41, April 1964.

D. 12. 36 J. Allen, et al., "Evaluation of Solid Propellants and Solid–Propellant Systems for Space Applications," Summary Report, Battelle Memorial Institute, Columbus, Ohio, 31 August 1963.

Prolonged storage of solid propellant rocket motors and effect on ultimate performance were evaluated in a combined experimental and analytical program.

D. 12. 37 M. DeFries, "A Feasibility Study for NDT of Solid Propellants," ARC Report RTD-TDR-63-1106, August 1963.

D. 12. 38 J. Tormey, and S. Britton, "Effects of Cyclic Loading on Solid Propellant Grain Structures," AIAA Journal, vol. 1, pp. 1763-1770, August 1963.

D. 12. 39 "Radiation Effects on Propellants," a list of references prepared by Battelle Memorial Institute, REIC, CPIA Publication No. 15, April 1963.

D. 12. 40 R. Landel, and B. Moser, "The Effects of Moisture on the Dynamic Mechanical Properties of Ammonium Perchlorate-Polyurethane Propellants," Jet Propulsion Laboratory Technical Report No. 32-389, 26 February 1963.

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D. 12. 43 C. Surland, "Combined Dilatometric and Uniaxial Hydrostatic Compliance Measurements to Evaluate Bulk Viscoelastic and Anisotropic Effects in Composite Propellants," Bulletin of First Meeting ICRPG Working Group on Mechanical Behavior, December 1962.

D. 12. 44 G. J. Svob, "Fatigue Properties of Polyurethane Propellant and Liner-Propellant Adhesive Bonds," Bulletin of First Meeting ICRPG Working Group on Mechanical Behavior, December 1962.

D.12.45 L. Layton, "Determination of the Dynamic Shear Modulus of a Composite Solid Propellant," Bulletin of First Meeting ICRPG Working Group on Mechanical Behavior, December 1962.

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D.12.48 K. Sweeney, "Curing Studies with Torsion Pendulum," Bulletin of First Meeting ICRPG Working Group on Mechanical Behavior, December 1962.

D.12.49 F. McIntosh and G. Mangum, "Advancement of Solid Propellant Rocketry," Quarterly Progress Report No. 27-62, Control C-A-62-27A, Thiokol Chemical Corp., Alpha Division, Huntsville, Alabama, 49 pp. April-June 1962, 30 October 1962. (C)

Improved aging characteristics of polybutadiene-type propellants. Presence of moisture during processing is discussed. Results of 8 weeks of aging of HC/imine propellant is reported.

D.12.50 N. Gorman, F. Murphy, "Progress in the Ten-Year Surveillance Program of Double Base and Composite Propellants, Rockets, and JATO's," Task Memo 1088, X63-10725, Picatinny Arsenal, Dover, New Jersey, October 1962. (C)

D.12.51 "Bulletin of Combined Panel Meeting," Report No. SPIA/AC-18, 18th Joint Army-Navy-Air Force Panel on Analytical Chemistry of Solid Propellants, 4th JANAF Panel on Analytical Chemistry of Liquid Propellants, SPIA, Applied Physics Laboratory, The John Hopkins University, Silver Spring, Maryland, 251 pp. October 1962. (C)

A. "Thermal Stability of a Broad Range of Solid Composite Propellants," M. Visnov, Frankford Arsenal

B. "Ambient Temperature Propellant Surveillance," S. Wachtell, Picatinny Arsenal

C. "The Effects of Space Aging on Solid Composite Propellants," R.A. Biddle

D. "Some Comments and Suggestions on the Surveillance and Aging of Composite Propellants," J.L. Myers, Aerojet-General Corp.

M. "Some Statistical Concepts for Panel Applications," R. Pierson, U.S. Naval Ordnance Test Station

U. "Survey of Analytical Procedures for Aging Studies of Propellants," H. A. Read, Hercules Powder Company

D. 12. 52 H. Driscoll, "The Effect of Relative Humidity on Cast Modified Double Base Propellants," Report No. A601216, Hercules Powder Co., Cumberland, Maryland, 21 August 1962.

To determine the effect of relative humidity on the physical properties of cast modified double base propellants.

D. 12. 53 AGC Report, R-SRP-304, "Electronic Monitoring of Propellant Quality," July 1962.

D. 12. 54 "Advancement of Solid Propellant Rocketry," Quarterly Progress Report No. 10-62, Control No. C-A-62-10A, Thiokol Chemical Corp., Redstone Arsenal, Redstone, Alabama, July-September 1961; 34 pp., 16 April 1962.

A long-term aging and surveillance study of polybutadiene propellants.

D. 12. 55 M. Roth and M. Younginer, "Prediction of the Effects of Storage on ARP Propellant by Means of Chemical Analysis," Technical Notes No. FRL-TN-126 (File No. F3628), Picatinny Arsenal, Dover, New Jersey, 11 pp., March 1962.

Effects of storage at 65.5° and 80°C on stabilizer content and viscosity of ARP propellant. Equations developed. Need verification in motors.

D. 12. 56 "Study of Mechanical Properties of Solid Rocket Propellants," Report No. 0411-10F, under Contract AF 33(600)-40314, Aerojet-General Corp., March 1962.

D. 12. 57 J. Allen, et al., "Evaluation of Solid Propellants and Solid Propellant Systems for Space Applications," 31 March 1962 - 30 June 1962, 3rd and 4th Quarterly Reports, April-June, Battelle Memorial Institute, Columbus, Ohio, 20 pp., January-March 1962.

Data on PBAA and PBAN propellants containing AP and A after subjecting them to radiation and vacuum-thermal conditions.

D. 12. 58 G. Dolgonas and N. Gardner, "Effects of Environment on Rocket Motor Operation," preprint 2305-62, ARS Solid Propellant Rocket Conference, Baylor University, Waco, Texas, 24-26 January 1962.

Discussion of the effects of environmental conditions on propellant used in tactical-type solid propellant motors.

D. 12.59 J. Allen, et al., "Evaluation of Solid Propellants and Solid Propellant Systems for Space Applications," Battelle Memorial Institute, Columbus, Ohio, 31 December 1961.

Plans to subject propellant samples to radiation/vacuum/thermal environment.

D. 12.60 R. Gardner, "Effects of Ionizing Radiation on Solid Rocket Motor Components, "Technical Report No. 32-234 (File No. F3529) Jet Propulsion Laboratory, Pasadena, California, 16 pp., 21 December 1961.

One-year storage in orbit and sterilization of 1.1×10^7 rads. About 10^7 rads due to sterilization. PBAA propellants withstand this dosage. Polyurethane and double base show marked degradation. Largest dosage applied to case and nozzle. Most critical part is believed to be liner. No data available of radiation on adhesion.

D. 12.61 C. Herty, "Change in Solid Propellant Mechanical Properties on Extended Storage at Low Temperatures, "Bulletin of 6th Meeting of JANAF-ARPA-NASA Solid Propellant Surveillance Panel, December 1961.

D. 12.62 W. Klemm, and G. Cenn, "Degradation Rate Studies of Certain Polybutadiene Terpolymer Propellants," Bulletin of 6th Meeting of JANAF-ARPA-NASA Solid Propellant Surveillance Panel, December 1961.

D. 12.63 R. Phillips, and J. Gibson, "Stability of Double Base Propellants," Bulletin of Sixth Meeting of JANAF-ARPA-NASA Solid Propellant Surveillance Panel, December 1961.

D. 12.64 W. Stapleton, "Techniques for the Microscopic Examination of Solid Propellants," Bulletin of the Sixth Meeting of JANAF-ARPA-NASA Solid Propellant Surveillance Panel, December 1961.

D. 12.65 J. Pakulak, Jr., "Safe Life Prediction of Propellants from Thermal Studies," Bulletin of the Sixth Meeting of JANAF-ARPA-NASA Solid Propellant Surveillance Panel, December 1961.

D. 12.66 M. E. Levy, and C. F. Murray, "Limitations in Use of Accelerated Testing to Evaluate Ballistic Stability," Bulletin of the Sixth Meeting of JANAF-ARPA-NASA Solid Propellant Surveillance Panel, December 1961.

D.12.67 "Study of Methods for Improving Storage Life of Solid Rocket Motors," Report No. 0411-01F, (Final, Part II) (File No. F 2952) Aerojet-General Corp., Sacramento, California. 15 pp., 21 January - 30 November 1961. (C)

A 24-motor aging demonstration program. Two polyurethane configurations. One Configuration failed after 90 days at 180°F; remaining motors of first configuration were one extensive bond. The second configuration liner began to degrade after 55 days at 180°F; motors fired successfully at 75° and 180°F.

D.12.68 J. Hoebel, "The Use of the Fil Dynamic Tester to Measure Propellant Dynamic Shear Properties," 20th Meeting Bulletin, JANAF-ARPA-NASA Panel on Physical Properties of Solid Propellants, vol. II, SPIA/PP14C, October 1961.

D.12.69 R. Spangler, "A Biaxial Stress-Strain Test for Solid Rocket Propellants," 20th Meeting Bulletin, JANAF-ARPA-NASA Panel on Physical Properties of Solid Propellants, vol. II, SPIA/PP14C, October 1961.

D.12.70 J. Wise, "The Development of a Specimen and Test Method to Provide Accurate Uniaxial Tension Mechanical Properties," 20th Meeting Bulletin, JANAF-ARPA-NASA Panel on Physical Properties of Solid Propellants, vol. II, SPIA/PP14C, October 1961.

D.12.71 M. Cooper, and J. Baldwin, "Development of a Bonded End Tensile Specimens," 20th Meeting Bulletin, JANAF-ARPA-NASA Panel on Physical Properties of Solid Propellants, vol. II, SPIA/PP14C, October 1961.

D.12.72 J. Brisbane, "Further Development of a Biaxial Stress Test for Viscoelastic Materials," 20th Meeting Bulletin, JANAF-ARPA-NASA Panel on Physical Properties of Solid Propellants, vol. II, SPIA/PP14C, October 1961.

D.12.73 D. Nicholson, D. Blomquist, and R. Lemon, "An Experimental Technique for Determining the Dynamic Tensile Modulus of Viscoelastic Materials," 20th Meeting Bulletin, JANAF-ARPA-NASA Panel on Physical Properties of Solid Propellants, vol. II, SPIA/PP14C, October 1961.

D.12.74 G. Svob, et al., "Volume Changes in Polyurethane Propellants Subjected to Small Strains," 20th Meeting Bulletin, JANAF-ARPA-NASA Panel on Physical Properties of Solid Propellants, vol. II, SPIA/PP14C, October 1961.

D.12.75 R. Kruse, "Dilatometric Behavior of Composite Solid Propellants under Uniaxial Tension," 20th Meeting Bulletin, JANAF-ARPA-NASA Panel on Physical Properties of Solid Propellants, vol. II, SPIA/PP14C, October 1961.

D. 12. 76 N. Wopland, "An Apparatus for Measuring the Bulk Modulus of Solid Propellants," 20th Meeting Bulletin, JANAF-ARPA-NASA Panel on Physical Properties of Solid Propellants, vol. II, SPIA/PP14C, October 1961.

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D. 12. 78 W. Knauss, "Displacements in an Axially Accelerated Solid Propellant Rocket Grain," Bulletin of the 20th Meeting of the JANAF-ARPA-NASA Panel on Physical Properties of Solid Propellants, SPIA Publication PP 14u, pp. 175-191, October 1961.

D. 12. 79 C. Herty, "Changes in Solid Propellant Mechanical Properties on Extended Storage at Low Temperatures," Bulletin of the Sixth Meeting JANAF Solid Propellant Surveillance Panel, SPIA Publication SPSP/pp. 105-114, October 1961.

D. 12. 80 R. Chase, and B. Iwanciow, "Propellant Slump in Large Solid Rocket Motors During Long-Term Vertical Storage," Bulletin of the 20th Meeting of the JANAF-ARPA-NASA Panel on Physical Properties of Solid Propellants, SPIA Publication PP14u, pp. 121-131, October 1961.

D. 12. 81 J. Fitzgerald, T. Harrison, and E. Francis, "Axial Slump of a Circular Port Grain," Bulletin of the 20th Meeting of the JANAF-ARPA-NASA Panel on Physical Properties of Solid Propellants, SPIA Publication PP14u, pp. 157-162, October 1961.

D. 12. 82 W. Milloway and J. Wiegand, "Failure Criteria for Some Polyurethane Propellants," Bulletin of the 20th Meeting of the JANAF-ARPA-NASA Panel on Physical Properties of Solid Propellants, SPIA Publication PP14u, pp. 323-340, October 1961.

D. 12. 83 "Study of Methods of Improving Storage Life of Solid Rocket Motors," Report No. 0411-01F (Final, Part I) Aerojet-General Corp., Sacramento, California, 21 June 1960 - 21 June 1961; August 1961. (C)

Propellant and liner investigations were conducted to determine methods of improving storage life. Studies were also made towards development of elastomers for O-rings with improved aging characteristics.

D. 12.84 W. Klemm, et al., "A Study to Improve Storage Properties of Solid Propellants," Report No. 513-F, (Final) Grand Central Rocket Company, Redlands, California, 18 January 1960 - 17 April 1961; July 1961. (C)

CBAN propellants were characterized with respect to degradative changes in mechanical properties during storage at temperatures varying from 0°F to 220°F under several environmental atmospheres.

D. 12.85 E. Criscuolo and D. Polansky, "State of the Art in Nondestructive Testing of Solid Propellants," Review Paper No. 5, AD-331138, Contract No. NOw 62-0604-C, U.S. Naval Ordnance Laboratory, White Oak, Silver Springs, Maryland, June 1961. (C)

D. 12.86 "A Study of Methods of Improving the Shelf Life of Solid Propellant Rocket Engines," Report No. E115-61, (Final) vols. I and II, Thiokol Chemical Corp., Elkton, Maryland, 18 May 1960-17 May 1961. (C)

Describes studies to determine the causes of aging for propellants and igniters. Associated studies of liners, sealant materials, and insulation are also reported.

D. 12.87 R. Ehrgott, "Ballistic Stability Study of M15 and M17 Propellants," Technical Report No. DR-TR: 1-61, Picatinny Arsenal, Ammunition Group, Dover, New Jersey, April 1961.

An elevated temperature (122°F) storage program to evaluate ballistic and chemical stability of M15 and M17 propellants.

D. 12.88 "Solid Propellant Aging Studies," Stanford Research Institute Quarterly Reports IV, VIII, and XII (Annual Summary Reports) under Contract AF 33(616)-5806, June 1959, May 1960, and April 1961. (C)

D. 12.89 R. Beyer, et al., "Solid Propellant Aging Studies," Report No. 34, Quarterly Progress Report No. 12, Annual Summary Report, Stanford Research Institute, Menlo Park, California, 31 March 1960-31 March 1961; 31 March 1961. (C)

To determine aging rates of propellants by most sensitive means possible. Propellant compositions for the three stages of Minuteman will be studied for up to 24 weeks of storage.

D. 12.90 E. Sienicki, et al., "A Study of Methods of Improving Shelf Life of Solid Propellant Rocket Engines," Report No. E-36-61, Quarterly Progress Report No. 3, Thiokol Chemical Corp., Elkton Division, Elkton, Maryland, 18 November 1960 - 17 February 1961; 17 March 1961. (C)

D.12.91 F. Cunningham, et al., "A Study of Methods of Improving Shelf Life of Solid Propellant Rocket Motors," Report No. E241-60, Quarterly Progress Report No. 2, Thiokol Chemical Corp., Elkton Division, Elkton, Maryland, 13 January 1961; 18 August-17 November 1960. (C)

Reports on causes of aging of PBAA, polyurethane and polysulfide propellant; boron potassium nitrate pellet igniters; liners; sealants; and insulation materials.

D.12.92 L.M. Brown, et al., "Quarterly Progress Report on Interior Ballistics," Report No. P-60-7, Rohm and Haas Co., Redstone Arsenal, Research Division, Redstone, Alabama, 75 pp., 15 January - 15 April 1960; 6 December 1960. (C)

Missile A: reports on effects of missile acceleration on grain integrity. 80 g's appears not to cause propellant breakup.

D.12.93 R. Beyer, et al., "Solid Propellant Aging Studies," Report No. 31, Quarterly Progress Report No. elevan, Stanford Research Institute, Menlo Park, California, 36 pp., October-December 1960. (C)

Reports on study of aging behavior of solid propellants. Endeavors to develop non-destructive tests to ascertain age of propellant, predicted on propellant being the weak link component.

D.12.94 G. Skopp, "Basic Investigation of the Operation of Propellant PAD-Actuated Devices in Space Environment, Phase I, A Study; Phase II, A Theoretical Study," WADD TR 60-346, Frankford Arsenal Report R-1545; WADD TR 60-347, Frankford Arsenal Report R-1546; Frankford Arsenal, Wright Air Development Division, Wright-Patterson Air Force Base, Dayton, Ohio, November 1960.

Phase I entails a compilation of the environments and a bibliography; Phase II contains preliminary studies conducted on the effects of environment on standard PAD.

D.12.95 R. Beyer, et al., "Solid Propellant Aging Studies," Report No. 28, Quarterly Progress Report No. 10, June 30 - September 1960, Stanford Research Institute, Menlo Park, California, 10 October 1960. (C)

Studies on solid propellant aging, including a bibliography of non-destructive testing literature brought up to date.

D.12.96 H. Jones, "A Study of Methods of Improving Shelf Life of Solid Propellant Rocket Engines," 18 May-17 August 1960, Report No. E 179-60, Quarterly Report No. 1, Thiokol Chemical Corp., Elkton Division, Elkton, Maryland, 6 October 1960. (C)

Discusses various aspects of propellant aging. Phase III program effort will recommend component modifications that will extend the useful life of the rocket engine as a unit.

D.12.97 J. Haygood, "Study of Methods of Improving Shelf Life of Existing and Contemplated Solid Rocket Motors," July 1958 - October 1959; Report No. 0217-01F, Aerojet-General Corp., Sacramento, California, 22 September 1960. (C)

Determines characteristics of the MD-1 rocket motor for the Genie, indicating that substantial improvement in aging stability of the propellant could be made.

D.12.98 R. Davis and R. Hollingsworth, "Ten-Year Summary of Aging Polysulfide-Perchlorate Propellants," Report No. 36-60, Control No. C-A-36A, vol. I, and Control No. C-A-60-36B, vol. II, October 1949-December 1959, Thiokol Chemical Corp., Redstone Division, Huntsville, Alabama, 19 September 1960. (C)

Concludes that this propellant would, have a serviceable life of at least 6 to 7 years under normal conditions.

D.12.99 H. Fong, C. Gustavson, et al., "A New Test for Evaluating Liner-Propellant Bonds under Constant Strain Conditions," Bulletin of Joint Meeting JANAF Panels on Physical Properties and Surveillance of Solid Propellants, September 1960.

D.12.100 J. Baldwin, "Preliminary Report on a Bonded Tensile Specimen," Bulletin of Joint Meeting JANAF Panels on Physical Properties and Surveillance of Solid Propellants, September 1960.

D.12.101 J. Fitzgerald, "A Biaxial Test for Solid Propellants," Bulletin of Joint Meeting JANAF Panels on Physical Properties and Surveillance of Solid Propellants, September 1960.

D.12.102 J. Martner, and N. Fishman, "An Ultrasonic Method of Nondestructive Evaluation of Propellant Physical Properties," Bulletin of Joint Meeting JANAF Panels on Physical Properties and Surveillance of Solid Propellants, September 1960.

D.12.103 R. Rainbird and J. Vernon, "An Instrument for Measurement of Volume Changes Occurring in Tensile Testing," Bulletin of Joint Meeting, JANAF Panels on Physical Properties and Surveillance of Solid Propellants, September 1960.

D.12.104 R.R. Burgartl, J. Frazer, and S. Britton, "The Evaluation of Propellant Mechanical Properties with the Alinco High Rate of Strain Tester," Bulletin of Joint Meeting, JANAF Panels on Physical Properties and Surveillance of Solid Propellants, September 1960.

D.12.105 A.J. Ignatowski and L.W. Jenkins, "A Nondestructive Technique for Determining the Integrity of Case-Bonded Propellant Motors," Bulletin of Joint Meeting, JANAF Panels on Physical Properties and Surveillance of Solid Propellants, September 1960.

D.12.106 "Transactions of the Fifth Symposium on Ballistic Missiles at Space Technology, Volume II: Propulsion," Report No. ASTIA AD323-311, Space Technology Laboratories and Aerospace (AFBMD), Los Angeles, California, 28-31 August 1960.

A. Radiation effects on composite propellants.

D.12.107 J. Vernon, "The Effect of Confining Pressure on the Mechanical Properties of Solid Propellants," pp. 1-23, Bulletin of the Meeting, 19th Meeting of the JANAF on Physical Properties and 5th Meeting of the JANAF Surveillance Panel, SPIA Publication, pp 13/SPSP8, August 1960.

D.12.108 S. Anderson, et al, "Quarterly Progress Report on Interior Ballistics," Report No. P-60-13, Rohm and Haas Company, Redstone Arsenal Research Division, Redstone, Alabama, 53 pp, 15 April-15 July 1960, 19 January 1960.

Missile A: Nike Zeus and second stage Pershing, utilizing internal measurements; propellant physical properties and motor geometry interactions to measure profile.

D.12.109 L. Christensen and B. White, "Aging Properties of Solid Propellants for Rocket Motors," Report No. 75, 30 June 1957, Stanford Research Institute, Menlo Park, California, 26 June 1960. (C)

Program concentrates on detection of adverse propellant aging properties and on understanding the aging characteristics.

D.12.110 R. Beyer and N. Fishman, "Solid Propellant Aging Studies," Report No. 25, Quarterly Progress Report No. 9, 31 March - 30 June 1960, Stanford Research Institute, Menlo Park, California, 24 June 1960. (C)

To develop information enabling prediction of serviceable life, and non-destructive techniques for determining the age of such motors.

D.12.111 F. Crescenzo, et al., "Process Development Division Quarterly Progress," NOTS TP 2571, Technical Progress Report 255, U.S. Naval Ordnance Test Station, China Lake, California, February-April 1960. (C)

A polyurethane propellant containing 57.3 percent ammonium perchlorate and 17.7 percent aluminum was prepared with a binder system based on the P-26 liner composition. Aging studies indicate that tensile strength and elongation gradually increase during the first 10 days of storage at 110° F, and thereafter exhibit no serious degradation at that temperature.

D.12.112 R. Beyer and N. Fishman, "Solid Propellant Aging Studies," Quarterly Progress Report No. 8, Annual Summary Report No. 22, 15 May 1959-31 March 1960, Stanford Research Institute, Menlo Park, California. (C)

Completed laboratory surveillance program on propellant aging begun in 1958.

D.12.113 R. Beyer and N. Fishman, "Solid Propellant Aging Studies," Report No. 20, Quarterly Report No. 7, November 1959 - January 1960, Stanford Research Institute, Menlo Park, California, 20 February 1960. (C)

Evaluate various propellants for relative storage behavior.

D.12.114 "Bulletin of the 4th Meeting, JANAF Solid Propellant Surveillance Panel," SPIA Publication SP SP/7, November 1959, Salt Lake City, Utah, 10-11 December 1959. (C)

Contains papers from a symposium on degradation mechanisms and from a symposium on use of physical properties tests in surveillance.

D.12.115 N. Beach, "The Quick Test for On-Site Detection of Deterioration in Conventional-Weapons Propellants," Bulletin of Fourth Meeting of JANAF Solid Propellant Surveillance Panel, December 1959.

D.12.116 R. Beyer, "A Study of Propellant Aging by Creep and Stress Relaxation Techniques," Bulletin of Fourth Meeting of JANAF Solid Propellant Surveillance Panel, December 1959.

D.12.117 M. Blumberg, J. Gallagher, C. Vriesen, "Crystallization Studies of Propellant Binder Systems by Constant Temperature Retraction Techniques," Bulletin of Fourth Meeting of JANAF Solid Propellant Surveillance Panel, December 1959.

D.12.118 S. Goldhagen, H. Taylor, H. Fong, "Improved Techniques for Obtaining Propellant Samples," Bulletin of Fourth Meeting of JANAF Solid Propellant Surveillance Panel, December 1959.

D.12.119 K. Haley, "Autoxidation Characteristics of Composite PBAA Propellant System," Bulletin of the Fourth Meeting of the JANAF Solid Propellant Surveillance Panel, SPIA Publication SP SP/7, pp. 1-24 December 1959.

D.12.120 A. Jacobs, J. Morton, and R. Downey, "Thermal Stability of Modified Double-Base Propellants," Bulletin of the Fourth Meeting of the JANAF Solid Propellant Surveillance Panel, SPIA Publication SP SP/7, pp. 25-54, December 1959. (C)

D.12.121 "Solid Propellant Aging Studies," Rocketdyne Report R-4007, under Contract AF 33(616)-5813, November 1959. (C)

D.12.122 R. Beyer, "Solid Propellant Aging Studies," Report No. 17, Quarterly Progress Report No. 6, Stanford Research Institute, Menlo Park, California, 20 November 1959. (C)

Laboratory aging tests were run on several different propellants. Three types of sonic technique were studied with several propellants and rubber samples.

D.12.123 T. Smith, "Use of Mechanical Property Tests for Evaluating the Storage Stability of Composite Propellants," Bulletin of the Fourth Meeting of the JANAF Solid Propellant Surveillance Panel, SPIA Publication SPSP/7, pp. 109-129, November 1959.

D.12.124 "Status of Research and Engineering Projects (Cast Double-Base Propellants)," Report No. AB2/QPR15, Allegany Ballistics Laboratory, Cumberland, Maryland, 1 October 1959. (C)

Thermal stability testing using the cracking cube test revealed that test is now more severe than in the past.

D.12.125 "Research and Development Work on Cast Double-Base Propellant Rockets," November 1958, and January-September 1959, Imperial Chemical Industries, Ltd., U.K. (C)

Propellant modifications to improve crack life were investigated.

D.12.126 R. Beyer, "Solid Propellant Aging Studies," Report No. 14, (QPR No. V) 15 May-31 July 1959, Stanford Research Institute, Menlo Park, California, 20 August 1959.

Storage of polyurethane, polysulfide, and polybutadiene-acrylic acid propellants at 160° F was completed.

D.12.127 L. DeAngelis and G. Gardin, "Evaluation of Propellant Stability by Oxygen Taliani Test and Chemical Analysis," Memorandum Report No. 1229, Ballistic Research Laboratories, Aberdeen, Maryland, August 1959.

Accelerated aging at 80° C and the oxygen Taliani test have been used to make quantitative measurements of chemical stability for single base propellants.

D.12.128 D. Rosenberg and H. Drackenberger, "Studies Leading to the Extension of Environmental Limits of Solid Propellants," Report No. E 80-59, Thiokol Chemical Corp., Elkton Division, Elkton, Maryland, 23 July 1959. (C)

Relationship of exposure time and temperature to physical properties have been established for various propellants at temperatures of 250-300° F; adhesive strength of propellant-to-liner and liner-to-metal were also evaluated after temperature conditioning. Polysulfide propellants with excellent (8 hours) stability at 300° F were also tested.

D.12.129 J. Haygood, "Study of Methods of Improving Shelf Life of Existing and Contemplated Solid Rocket Motors," Report No. 0217-01Q-4, Aerojet-General Corp., Sacramento, California, 20 July 1959.

69 aged MD-1 motors and 72 igniters were disassembled and inspected. No changes in chamber-to-liner bond were detected. Liner-to-propellant bond appears satisfactory. Propellant properties suggest that higher temperature accelerated aging is not simple equivalent to greater time at lower temperature.

D. 12. 130 E. Cooke, et al., "Composite Propellants Based on Polyester Polyurethane Rubber," developments in 1958, Technical Memorandum ERDE 20/R/59, Explosive Research and Development Establishment, Waltham Abbey, July 1959. (C)

Aging trials have shown that with many compositions there is no deterioration after 9 months at 60° C under dry conditions; under humid conditions, degradation is rapid.

D. 12. 131 W. Dowler, G. Lewis and L. Stimpson, "Torsion Testing of Solid Propellants," Bulletin of 18th Meeting of JANAF Panel on Physical Properties of Solid Propellants, SPIA/PP12, June 1959.

D. 12. 132 H. Brettschneider, "Determination of Hydrostatic Compressibility of Solid Rocket Motor Components," Bulletin of 18th Meeting of JANAF Panel on Physical Properties of Solid Propellants, SPIA/PP12, June 1959.

D. 12. 133 C. Surland and J. Jackobs, "Measurements of Triaxial Strains from Hydrostatic Stress," Bulletin of 18th Meeting of JANAF Panel on Physical Properties of Solid Propellants, SPIA/PP12, June 1959.

D. 12. 134 K. Bischel, "Significance of Mechanical Property Tests for the Evaluation of Nitrosol Propellants," Bulletin of 18th Meeting of JANAF Panel on Physical Properties of Solid Propellants, SPIA/PP12, June 1959.

D. 12. 135 M. Liebman and J. Wiegand, "The Role of Mechanical Properties in Reliability Programs for Large Solid Propellant Motors," Bulletin of 18th Meeting of JANAF Panel on Physical Properties of Solid Propellants, SPIA/PP12, June 1959.

D. 12. 136 J. Sherman and H. Burns, "Temperatures Produced in Solid Propellant Rockets by Exposure to Climatic Extremes," ABL/X-37, Allegany Ballistics Laboratory, Cumberland, Maryland, June 1959. (C)

Considers the upper temperature limit of 165° F too high considering worldwide climatological extremes. Recommends 130° F and 150° F respectively for 16- and 8-inch diameter rockets.

D. 12. 137 M. Fein and N. Schwartz, "Development of Solid Propellants for Application in Extended Temperature and Space Environmental Conditions," Report No. RMD 1147-Q1, Reaction Motors Division, Thiokol Chemical Corp., Elkton, Maryland, April-June 1959. (C)

Program goal is preparation of propellant thermally stable in cycling and storage temperature range from -65° F to 500° F.

D.12.138 "Development of Composite Propellants and Rocket Motors," Research Summary Nos. 1 and 2. December 1958-April 1959, Jet Propulsion Laboratory, Pasadena, California, 15 April 1959.

Storage stability of several different propellants were investigated.

D.12.139 R. Moorehead, et al., "Development of Solid Composite P- ellants for High Temperature Operation," Report No. .0-01-6, January-March 1959, Aerojet-General Corp., Sacramento, California, 10 April 1959. (C)

Igniters aged at 300° F for 6 hours were successful for only one igniter. Development of igniters and propellants for use at 300 and 500° F was continued.

D.12.140 J. McGarry, et al., "Study and Improvement of Storage Capabilities of Solid Propellant Motors," Report No. E59-59 (QPR No. 3), Thiokol Chemical Corp., Elkton, Maryland, 31 March 1959. (C)

Accelerated aging of old motors at 170° F was discontinued after 12 motors so aged were all found to have cracked propellant. BA-107 (polybutadiene-acrylic acid) and DA 104 (polyurethane) propellants were found to have better aging capabilities than TRX-237 (polysulfide). Propellant formulations are being aged at -20° F for 10 months. Proposals are being considered for determination of molecular weights of aged propellant and aged igniters.

D.12.141 J. Myers, et al., "Quarterly Progress Report, Analytical Section, Explosives Wing," Technical Memorandum 235/59 October-December 1958, Canadian Armament Research and Development Establishment, March 1959. (C)

The surveillance program on propellants for the 7.62 mm. round is now completed, but some related problems still exist.

D.12.142 "Aging Effects of Plasticizer Migration in Double-Base Propellant Grains," Report No. NOTS TP2150, NavOrd 6442, U.S. Naval Ordnance Test Station, Inyokern, California, 11 February 1959.

D.12.143 R. Hodgdon and R. Lait, "Solid Solution Rocket Propellants," First Quarterly Report, November 1958-February 1959, Monsanto Chemical Co., 1 February 1959. (C)

X-ray diffraction data on lithium perchlorate/polycaprolactam (70:30) after 7 months showed the presence of crystalline lithium perchlorate trihydrate.

D.12.144 F. Warren, et al., "Evaluation of Solid Propellant Properties, Part I, A Survey of Current Methods; Part II, A Critical Examination of Current Methods," Report No. R5289, Southwest Research Institute, 31 January 1959. (C)

The survey covers test procedures for solid propellant surveillance.

D.12.145 R. Beyer and N. Fishman, "Aging Properties of Solid Propellants for Rocket Motors (Ignition Studies with the Arc Image Furnace)," Report No. 59, Technical Report No. IV, Stanford Research Institute, Menlo Park, California, 10 January 1959. (C)

It was found that changes in ignitability on aging are largely due to surface modifications.

D.12.146 "Status of Research and Engineering Projects," ABL/QPR No. 9, Allegany Ballistics Laboratory, Cumberland, Maryland, 1 January 1959. (C)

Describes a surveillance program to determine the effect of storage temperatures on the propellant-chamber bond strength.

D.12.147 N. Beach and N. Garman, "Long Range Study of Prediction of Safe Life of Propellants," Technical Memorandum GL-1-59, Picatinny Arsenal, Dover, New Jersey, January 1959.

Stability tests of various propellants are evaluated.

D.12.148 J. Palsulak, Jr., and G. Leonard, "An Investigation of the Thermal Stability of Individual Constituents and Various Mixtures of the Constituents Occurring in Polyurethane Propellants," NOTS 2109, NAVORD Report 6411, Naval Ordnance Test Station, China Lake, California, 8 December 1958. (C)

Studies stability of a polyurethane propellant by differential thermal analysis.

D.12.149 N. Beach, "Investigation of the Stability of Deteriorating Propellants," Technical Memorandum GL-4-58, Picatinny Arsenal, Dover, New Jersey, December 1958.

Describes a long-range program for the storage of a wide range of propellant formulations.

D.12.150 C. Lenchitz, et al., "Development of Quantitative Tests for Establishment of Stability of Propellant," Technical Memorandum GL-5-58, Picatinny Arsenal, Dover, New Jersey, December 1958.

Substantiates that propellant stability tests are qualitative rather than quantitative.

D.12.151 S. Goldhagan and D. Holly, "Study Methods of Improving Shelf Life of Existing and Contemplated Solid Rocket Motors," Report No. 0217-01Q-1, July-September 1958, Contract AF33(616)-5814, Aerojet-General Corp., Sacramento, California, 6 pp., 3 figures, ? November 1958. (C)

Development of methods to improve the shelf life of existing and contemplated solid rocket motors.

D.12.152 N. Fishman, "Propellant Behavior at Low Temperatures," pp. 1-7, Bulletin of the Third Meeting of the JANAF Solid Propellant Surveillance, SPIA Publication Nos. SPSP/5 and SPSP/6, October 1958.

D.12.153 M. Morton, M. Ohta, and J. Berry, "Hydrolytic Degradation of Urethane Polymers," Proceedings of the JANAF Conference on Elastomer Research and Development, Fifth Meeting, vol. 2, October 1958.

D.12.154 J. Quinlan, "Solid Propellant Chemical Stability - A Survey," Technical Report No. R-1465, Frankford Arsenal, Wright-Patterson AFB, Dayton, Ohio, September 1958.

Survey made of available literature to determine the relationship between chemical stability of solid double-base propellants and the variation in nitroglycerine content and the degree of nitration of nitrocellulose.

D.12.155 W. Dale, Jr., and H. Brettschneider, "Exerpience with the Alinco High Rate Tensile Tester," Bulletin of 17th Meeting of JANAF Panel on Physical Properties of Solid Propellants, SPIA/PP11, May 1958.

D.12.156 K. Sweeny, "The Alinco High Rate Tester," Bulletin of 17th Meeting of JANAF Panel on Physical Properties of Solid Propellants, SPIA/PP11, May 1958.

D.12.157 J. Vernon, and R. Rainbird, "The Effect of Strain Rate on the Mechanical Properties of Solid Propellant of the Double Base Type," Bulletin of 17th Meeting of JANAF Panel on Phydical Properties of Solid Propellants, SPIA/PP11, May 1958.

D.12.158 K. Sweeny, and K. Bills, Jr., "Apparatus for the Measurement of Stress Relaxation Behavior," Bulletin of 17th Meeting of JANAF Panel on Physical Properties of Solid Propellants, SPIA/PP11, May 1958.

D.12.159 T. Smith, A. Havlik, et al., "Methods for Studying the Stability and Chemical Structure of Composite Propellants and their Polymeric Binders," Bulletin of Second Meeting JANAF Solid Propellant Surveillance Panel, SPSP/3, November 1957.

D. 12. 160 I. Cameron, and J. Myers, "Stability Studies of Small Arms Propellant," Bulletin of Second Meeting JANAF Solid Propellant Surveillance Panel, SPSP/3, November 1957.

D. 12. 161 "Monthly Progress Report, Cast Double-Base Propellant and Rocket Development," ABL/MPR 69, Allegany Ballistics Laboratory, Cumberland, Maryland, 51 pp., 14 tables, 7 figures, 1 June 1957. (C)

D. 12. 162 L. DeAngelis, "An Improved N/10 Methyl Violet Surveillance Test for Double-Base Propellants," Technical Note No. 1128, Ballistic Research Laboratories, Aberdeen Proving Ground, Aberdeen, Maryland, 14 pp., 1 figure, 1 table, June 1957.

Improved functioning of N/10 methyl violet papers used for detecting evidence of deterioration in filled surveillance testing of bulk propellants has been obtained on an experimental basis.

D. 12. 163 J. Swotinsky, et al., "Surveillance of Solid Rocket and Artillery Propellants," 42 pp., 24 tables, JANAF Solid Propellant Group Meeting Bulletin, Vol. III, p. 637, June 1957. (C)

Describes surveillance studies currently in progress at Picatinny Arsenal on solid rocket and artillery propellants.

D. 12. 164 "Development of Composite Propellant Booster Unit," Report No. 726-2-57RF, Phillips Petroleum Corporation, McGregor, Texas, 9 pp., 1 February-1 April 1957. (C)

Sixty days storage at 170° F of Propellant 135 indicated no propellant deterioration but the inhibitor and liner propagated failures.

D. 12. 165 "Monthly Progress Report, (Cast Double-Base Propellant and JATO Development)," ABL/MPR-64, Contract NOrd 16640, Allegany Ballistics Laboratory, Cumberland, Maryland, 36 pp., 7 tables, 14 figures, February 1957. (C)

High temperature storage of double-base propellant at 250° -300° F.

D. 12. 166 E. Costa, et al., "Research and Development on Rocket Propellants," Bimonthly Report No. SI, Picatinny Arsenal, Dover, New Jersey, 30 pp., 5 tables, 10 figures, November-December 1956. (C)

Two year surveillance of rocket motors stored at 122° F.

D.12.167 J. Grover, et al., "Research and Development Programs in Fields of Solid Propellant and Interior Ballistics," Quarterly Progress Report No. 23 (October-December 1955), Atlantic Research Corporation, Alexandria, Virginia, July 1956. (C)

An investigation of the thermal stability of arcite propellant.

D.12.168 C. Boyars, et al., "Compatibility of Propellant Ingredients," Memorandum Report No. 114, Naval Powder Factory, Indian Head, Maryland, 21 pp., 6 tables, 9 December 1955. (C)

Brief descriptions of techniques and data collected on compatibility of propellant ingredients coming in contact with various other materials.

D.12.169 "Use of Scale Models in Surveillance Testing for Plasticizer Migration in Rocket Grains," NOTS 1282 NavOrd 4960, U. S. Naval Ordnance Test Station, Inyokern, California, 11 November 1955.

D.12.170 F. Schoenfeld and A. Japs, "Solid Rocket Propellant Research," Report No. G-55-3, B. F. Goodrich Company, Breckville, Ohio, 12 pp., 15 tables, 12 figures, 1 October 1955. (C)

Reports aging characteristics of "C" rubber propellant compositions at room temperature and under accelerated conditions.

D.12.171 J. Clapp, et al., "Development of Turbostarter Cartridge," Report No. 968 (Summary), Aerojet-General Corp., Sacramento, California, 46 pp., 27 June 1955. (C)

A turbostarter-cartridge containing a 3.85-lb. charge of Aeroplex AN-2106AX propellant designed to operate for 10.5 sec at 60° F in an AF type P-1 starter was subjected to qualification testing after exposure to environmental conditions, aging, vibration, dropping, and temperature cycling.

D.12.172 K. Rumbel, et al., "Research and Development Programs in Fields of Solid Propellants and Interior Ballistics," QPR No. 20, Atlantic Research Corporation, Alexandria, Virginia, 47 pp., 13 tables, 17 figures, 1 appendix, January-March 1955. (C)

C - Development of Arcite propellants

Five-inch Arcite grains which have been stored at 160° F for months were successfully fired at -65° F.

D. 12.173 W. Lehman, "Qualification Tests of S-12 Solid Propellant Starter Cartridge," Report No. 65 (Final)(Bu Aer Proj. TED-ARTS-SI-5514), Naval Air Rocket Test Station, Lake Denmark, New York, 13 pp., 27 figures, 6 appendices, February 1955. (C)

Qualification tests on S-12 starter cartridges including environmental testing and short-term aging.

D. 12.174 D. Hardie, et al., "Report on Performance of Pressed Charges of RC2 Propellant After Cyclic and Accelerated Temperature Storage," Imperial Chemical Industries, Ltd. U.K., 26 pp., 3 tables, 2 figures, 12 graphs, March 1952. (C)

Temperature cycling of pressed charges was carried out at ambient, 65° C for 6 weeks and cycling (-26° to +45° C); no deterioration was noted.

D. 12.175 B. Alley and J. Higging, "X-ray Fluorescence Analysis of Aged Polysulfide-Ammonium-Perchlorate Propellants," Bulletin of the 15th Meeting, JANAF Solid Propellant Group, Army Rocket and Guide Missile Agency, Huntsville, Alabama, vol. VII, p. 353-377. (C)

X-ray fluorescence analyses of aged propellants have shown that progressive changes in surface concentration of polymer, oxidizer, and a few inorganic additives can be accurately determined.

D. 12.176 R. Beyer, "Solid Propellant Aging Studies," Report No. 12, QPR No. IV, Final Summary Report, Stanford Research Institute, Menlo Park, California. (C)

Manifestations of accelerated aging were dependent upon the size of the specimen being studied; polysulfide propellants showed the most severe effects of aging. Creep, shear strength, tensile strength, and microscopic analyses provided the most meaningful results.

D. 12.177 J. Myers and R. MacDonald, "Effects of Ingredients on the Stability of Polyurethane Propellants," (C)

D. 12.178 H. Schindler and J. Confides, "Effects of Three Years Storage at Magazine (55° F) and Elevated (122° F) Temperatures on T16 Propellant", Technical Report No. 2582, Picatinny Arsenal, Dover, New Jersey. (C)

A 10-year surveillance program on T16 extruded double-base propellant is being conducted.

D.12.179 "Elastic Properties of Solid Propellant as Control Parameters," X64-11695, Ogden Air Materiel Area, Hill AFB, Ogden, Utah.

D.12.180 "Propellant Storability and Life Time for Various Rocket Propulsion Systems," Report No. NAVWEPS-8570 X64-14269, U.S. Naval Propellant Plant, Indian Head, Maryland.

D.12.181 "Standardization of Strain Gauges for Solid Propellant Testing," Report No. CSTAR X64-11694, Ogden Air Materiel Area, Hill AFB, Ogden, Utah.

D.12.182 "Study and Improvement of Storage Capability of Solid Propellant Motors", Report No. E188-59, Thiokol Chemical Corp., Elkton, Maryland. (C)

Investigations of aging effects upon storage are given for a number of propellant formulations.

D.12.183 "Thin Layer Multi-directional Chromatography Used to Separate Propellant Stabilizers and Possible Degradation Products", RX-TR-63-29, X64-11437, Army Missile Command, Huntsville, Alabama.

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13 ABSTRACT

This report is intended to provide a single source reference document to literature dealing with aging and surveillance studies of solid rocket motor components and surveillance techniques. The bibliography contains over 1000 references, of which about 400 pertain to the MINUTEMAN Aging Program. Major emphasis has been given to the MINUTEMAN Program because TRW's participation in this program from its onset permitted a detailed review which should be of value to others planning new aging programs. Selected references are provided on 23 categories of solid rocket motors in addition to MINUTEMAN. Many reports are referenced which contain extensive information on the aging of the materials and components that are commonly used in solid rocket motors. The collected references are catalogued in a logical manner, and a narration is provided as a guide to the scope and nature of the references. Analysis and assessment of the collected literature on rocket component aging will be presented in a later report, which will include an updated bibliography.

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